FINAL REPORT
INVESTIGATION OF
AIRCRAFT POWERLINE TRANSIENTS
(PHASE IV)

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## ABSTRACT

An investigation into the extent and nature of switching transients on aircraft powerlines showed that both "on ground" and "in-flight" conditions are similar. The data also indicated that, of the transients resulting from switching operations and lasting less than 50 microseconds, more than 95% are similar to damped sinusoidal waveforms or unipolar waveforms; all are below 200V peak on the 115 Vac bus (400 Hz) and 24V peak on the 28 Vdc bus; 94% are below 25V on the 115 Vac (400 Hz) bus; and 82% are below 0.5V on the 28 Vdc bus.

Based on the findings, for test method CE07 in MIL-STD-461, Part 2 (Aircraft), the present levels are adequate and should be retained. For test method CS06:

a. The requirements should be modified to include two damped sinusoidal waveforms having a Q of 6, frequencies of 1.0 and 10.0 MHz and a peak amplitude at 200V for 115 Vac, 400 Hz powerlines. This requirement should also be added for 28 Vdc lines; however, the amplitude should be reduced to 24V peak.

b. The unipolar pulse with the present time durations should be retained except that the amplitude for the dc powerline should be reduced to 24V peak.

## 1. INTRODUCTION.

1.1. An investigation was conducted to determine the nature of electrical transients on the ac and dc powerlines of aircraft during routine operations on the ground or in flight. This was the last phase of a four-phase investigation to determine the nature of electrical transients on U.S. Government ships (Phase I) and shore stations (Phase II), and aboard U.S. Government aircraft (Phase IV). Phase III was an evaluation of commercial transient suppression devices to determine their effectiveness against electrical transients. Appendix A lists the reports on Phases I, II and III and other documents pertinent to the program.

1.2. U.S. Navy, U.S. Coast Guard, and other military aircraft were tested to obtain a data base of their electrical transient characteristics. Aircraft were selected according to their type, age, type of motive power, and electrical power generation system so that a wide sample, reflective of all government aircraft, would be represented. Table I lists the aircraft tested, the

TABLE I. AIRCRAFT TESTED

| Aircraft Type | ID Number | Flight Hrs. Logged | Test Date |
|---|---|---|---|
| On-ground | | | |
| A-7E | BUNO 160887 | 1,027 | 22 Nov 82 |
| UH-1N | BUNO 160624 | 640 | 26 Jan 83 |
| P-3C | BUNO 161415 | 45 | 21 Mar 83 |
| CH-46E | BUNO 153372 | 2,624 | 20 Sep 83 |
| HU-25A | CGNR 2110 | 689 | 18 Jun 84 |
| CH-46E (SR&M)* | BUNO 153362 | 4,692 | 31 Jul 84 |
| TF-18A | BUNO 161714 | 814 | 13 Dec 84 |
| ATF-2 | AFT 102 | 14 | 3 Apr 85 |
| RP-3D | BUNO 158227 | 11,712 | 10 Apr 85 |
| HH-65A | CGNR 6506 | 82 | 9 Sep 85 |
| HH-3F | CGNR 1470 | 10,134 | 16 Sep 85 |
| AV-8B | BUNO 161576 | 241 | 31 Oct 85 |
| HC-130H | CGNR 1713 | 10 | 9 Dec 85 |
| In-flight | | | |
| HC-130H | CGNR 1713 | 10 | 14 Aug 86 |
| HU-25A | CGNR 2110 | 689 | 27 Aug 86 |
| HH-3F | CGNR 1483 | 989 | 23 Oct 86 |

*The CH-46E (SR&M) aircraft is an extensively modified version of the CH-46E aircraft and was considered separately for this program.

dates they were tested, and their identification numbers. Appendix B presents general descriptions and historical information on each aircraft tested. Appendix C gives details on the power system configurations of the aircraft tested. Several sample pages of a typical event list (test plan) are included as appendix D and sample plots of the data recorded are provided in appendix E.

## 2. DESCRIPTIONS.

2.1. This report deals with transients, that is, interruptions to normal ac and dc power that last less than 50 microseconds. These interruptions are also called "spikes." The report does not take into consideration spikes caused by lightning strikes or electromagnetic pulses or interruptions lasting longer than 50 microseconds (called "sags" or "surges"); however, sags and surges were recorded for the last nine aircraft listed in table I and separate reports were issued on those analyses (see references 8 and 10 through 16 in appendix A).

2.2. Voltage spikes (or for the 400 Hz powerline frequency, RF noise that modulates a portion of the fundamental frequency powerline waveform) have a waveform shape similar to a critically damped sinusoidal oscillation that may approach a unipolar pulse. Figures 1 and 2 show the waveforms of these transients. Requirements for spikes lasting less than 50 microseconds are governed by MIL-E-6051 and MIL-STD-461.

2.3. Transient parameters were measured on the 115 Vac, 400 Hz and 28 Vdc power buses, the primary power systems used aboard the aircraft. The 26 Vac, 400 Hz bus is used only for flight instrumentation and represents a small load on aircraft power. It is

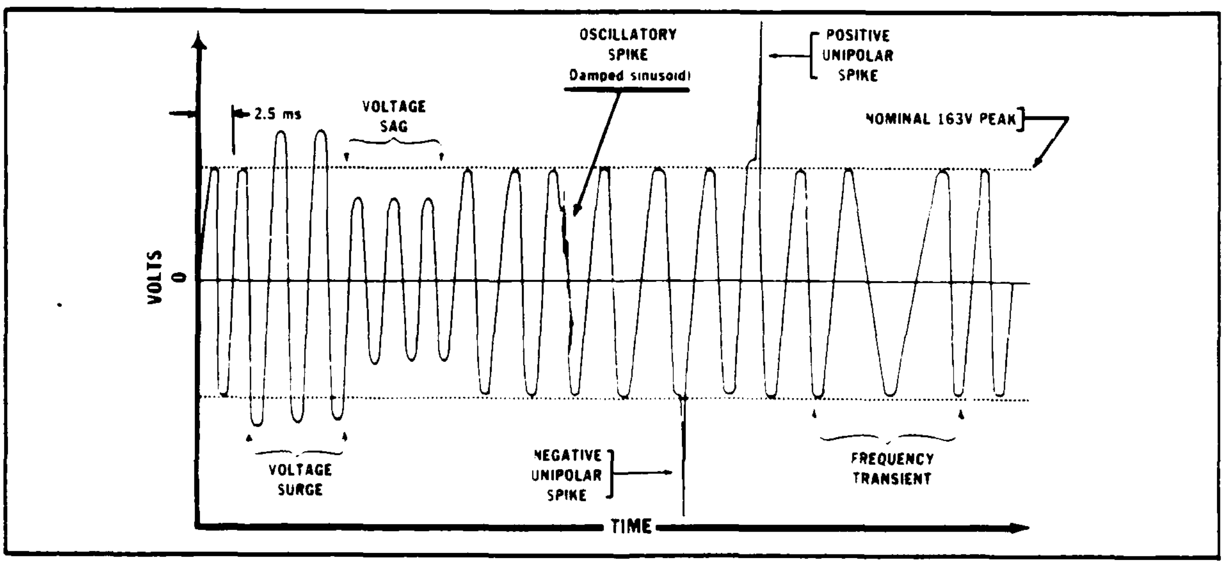



FIGURE 1. TYPICAL POWERLINE TRANSIENTS ON AC POWERLINES FOR NOMINAL 115 Vac (RMS), 400 Hz

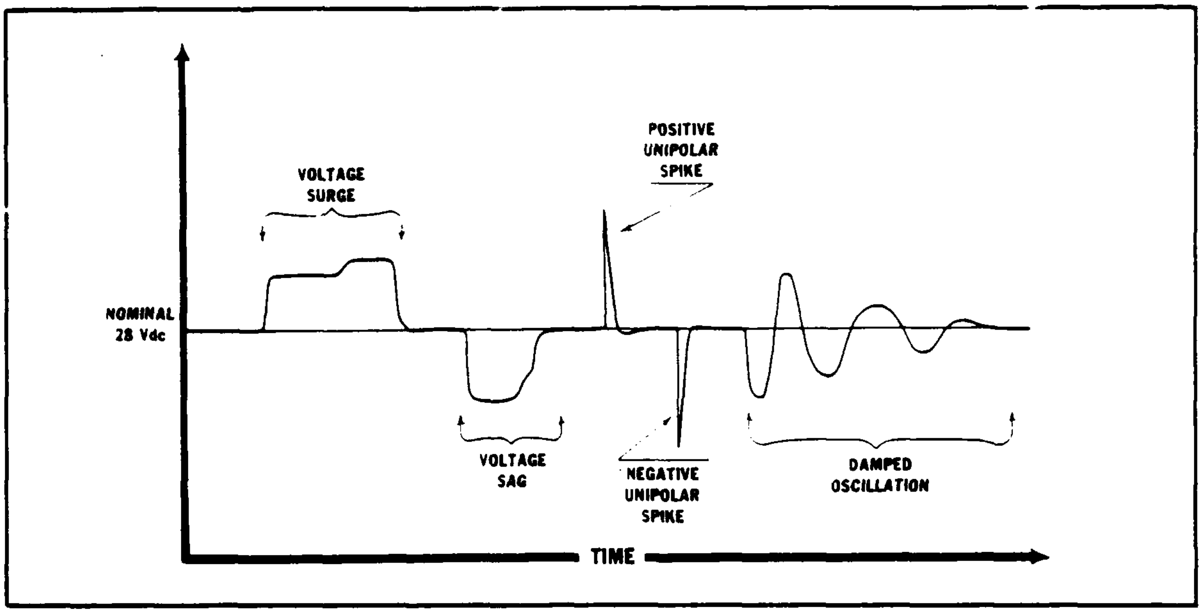



FIGURE 2. TYPICAL POWERLINE TRANSIENTS ON DC POWERLINES FOR NOMINAL 28 Vdc

always converted from one of the two primary power buses. Although two other systems (270 Vdc and 230 Vac, 400 Hz) are permitted for special purposes, none of the aircraft tested had them; therefore, the results and conclusions of this investigation are applicable only to 28 Vdc and 115 Vac, 400 Hz aircraft power systems. Figure 3 shows the power system equipment normally found in any aircraft.

2.4. A statistical analysis of the powerline transient data provided information regarding the peak amplitudes of powerline transients, the waveshape of the transients, and the frequencies of the transients; the information was used to determine whether existing military requirements were appropriate. The statistical analysis included transient data from the powerline investigations of all 14 aircraft. These investigations included tests on the ground and in flight. The on-ground tests included 11,581 separate switching operations performed while the aircraft were operated using both externally and internally supplied power. The in-flight tests included 1338 separate switching operations performed while the aircraft were flying. The in-flight tests included a large number of random transients and some power-up and power-down operations.

## 3. TEST RESULTS AND ANALYSIS.

3.1. Amplitudes. An analysis of the amplitude data from the 115 Vac, 400 Hz buses of the aircraft indicated that all the transients had peak amplitudes below 200V. Approximately 70% of

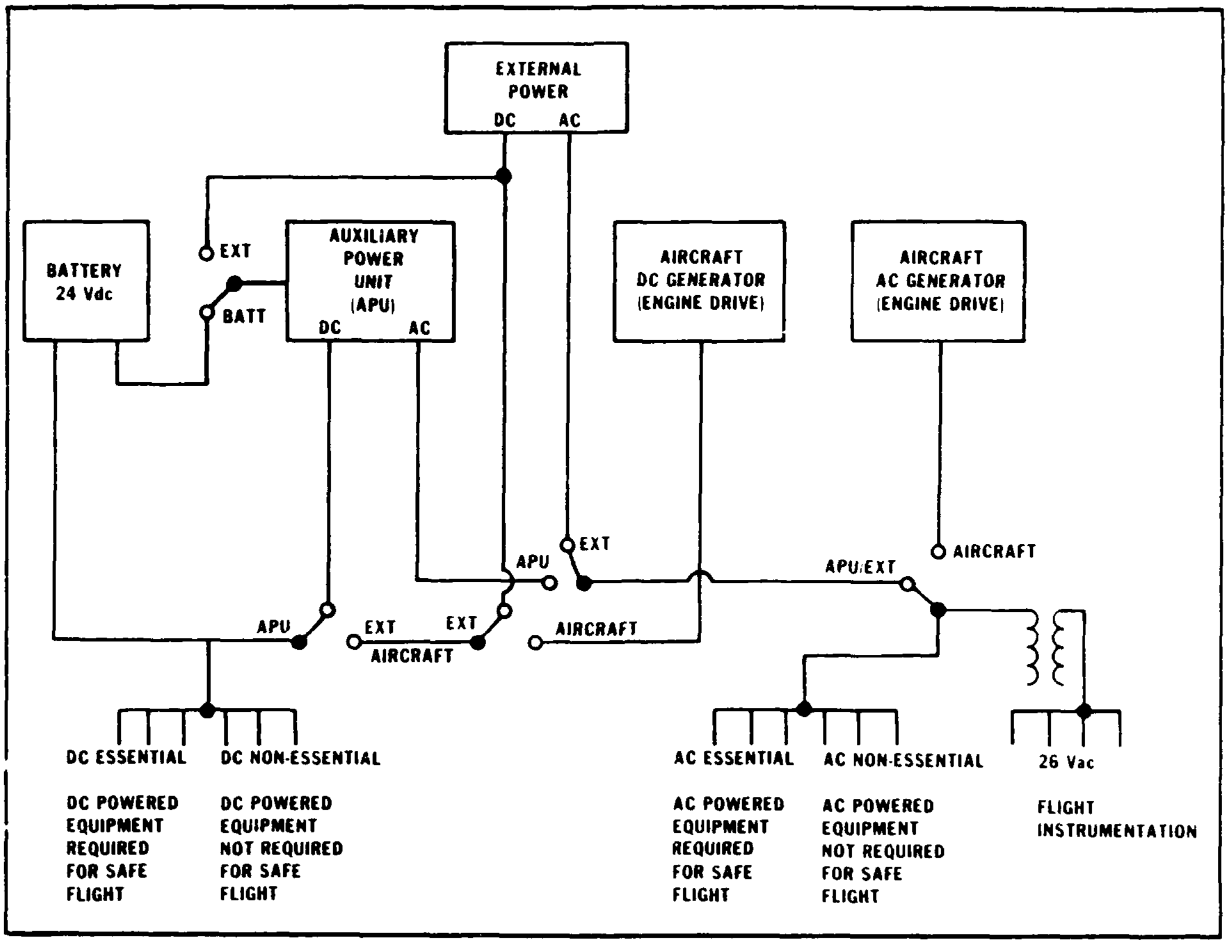



FIGURE 3. TYPICAL AIRCRAFT ELECTRICAL POWER SYSTEM FOR 28 Vdc AND 115 Vac (RMS), 400 Hz

these transients were below 50V. A similar analysis of the 28 Vdc bus data showed all transients had peak amplitudes less than or equal to 24V. Approximately 90% of all the transients on the 28 Vdc buses were less than 6V peak amplitude. Statistical analyses were performed for four different categories: (1) on-the-ground data according to the type of power source used; (2) the type of aircraft; (3) the age of the aircraft (flight hours), and (4) in flight performance. See table II.

3.1.1. AC Analysis. The results of the analysis of 115 Vac, 400 Hz power are shown in table III. The APU was used as a power source for only two aircraft, which may account for the small difference in its statistical results when compared to the overall data. In addition, testing was limited to three turbo-prop aircraft, of which two were operated using the main power generating systems. Discounting those two values in table III , on-the-ground test conditions can be used to predict the amplitude levels of transients occurring on the 115 Vac buses of aircraft in flight too.

TABLE II. AIRCRAFT CLASSIFICATION

| Aircraft | Power Source | | | Flight Hour Age | Aircraft Type |
|---|---|---|---|---|---|
| | External* | APU** | Engine | | |
| A-7E | X | | | 1,027 | Jet |
| HU-25A | X | | X | 689 | Jet |
| TF-18A | X | | | 814 | Jet |
| ATF-2 | X | | | 14 | Jet |
| AV-8B | X | | | 241 | Jet |
| UH-1N | X | | | 640 | Rotary Wing |
| CH-46E | X | | | 2,624 | Rotary Wing |
| CH-46E (SR&M) | X | | X | 4,692 | Rotary Wing |
| HH-65A | X | | X | 82 | Rotary Wing |
| HH-3F (CGNR 1483) | X | | X | 989 | Rotary Wing |
| HH-3F (CGNR 1470) | X | | | 10,134 | Rotary Wing |
| P-3C | X | | | 45 | Turbo-prop |
| RP-3D | X | X | X | 11,712 | Turbo-prop |
| HC-130H | X | X | X | 10 | Turbo-prop |

*External power included that from hangars, power carts, and deck edges.
**APU is an auxiliary power unit.

TABLE III. RESULTS OF AC AMPLITUDE TESTS

| On the Ground | | |
|---|---|---|
| Power Source | % of Transients | |
| | <50V Peak | <200V Peak |
| External | 90 | 100 |
| APU | 37 | 100 |
| Engine | 90 | 100 |
| Aircraft Type | | |
| Jet | 90 | 100 |
| Helicopter | 90 | 100 |
| Turbo-prop | 46 | 100 |
| Flight Hour Age | | |
| <100 | 90 | 100 |
| 100-1000 | 82 | 100 |
| >1000 | 60 | 100 |
| In Flight | | |
| Engine | 95 | 100 |

3.1.2. DC Analysis. The results of the analysis of 28 Vdc power are shown in table IV. For the in-flight test, the data recorded showed that the largest number of short duration transients occurred on the dc power buses of the HH-3F aircraft between 6V and 24V peak amplitude. This result affected the distribution percentages for all three in-flight tests. The HH-3F aircraft was not the same aircraft that was tested during on-ground tests. When the results from the HC-130H and the HU-25A were examined separately, the data indicated that the transient amplitude levels were either lower than or similar to those occurring when the aircraft was operated on the ground. The results indicated that the present MIL-STD-461B Test Method CE07 amplitude requirements for switching transients are adequate for instrumentation and power generation equipment connected to the 28 Vdc buses. The data and analysis also indicated that the 200V test spike required by MIL-STD-461B Test Method CS06 is excessive when applied to 28 Vdc lines. The amplitude of the test spike can be decreased to a level of 24V.

TABLE IV. RESULT OF DC AMPLITUDE TESTS

| On the Ground | | |
|---|---|---|
| | % of Transients | |
| Power Source | <6V Peak | <24V Peak |
| External | 90 | 100 |
| APU | 90 | 100 |
| Engine | 90 | 100 |
| Aircraft Type | | |
| Jet | 90 | 100 |
| Helicopter | 90 | 100 |
| Turbo-prop | 96 | 100 |
| Flight Hour Age | | |
| <100 | 90 | 100 |
| 100-1000 | 94 | 100 |
| >1000 | 91 | 100 |
| In Flight | | |
| Engine | 37 | 100 |

3.2. Transient Threshold Levels. In establishing the criteria for the transient thresholds for the data base, we considered two items. First, every switching action causes a transient of some level and some realistic lower threshold must therefore be set for the instrument. Second, since every switching action causes a transient disturbance and this disturbance may be in the form of a "pulse-train" or a series of disturbances, a limit must be applied to the length of time the disturbances are recorded. The following conditions were set for the data base:

a. Thresholds of 25 Vac (peak) and 0.5 Vdc (peak) had to be exceeded before the transient was included in the data base.

b. The rise time capability of the recording instrumentation was 20 nanoseconds.

c. Only the waveform with the highest amplitude (and its associated ringing action if present) was analyzed if a series of repetitive disturbances was recorded. Consequently, since current was being interrupted, we know that a transient occurred for every one of the switching operations of the tests; however, not all transients were recorded.

3.2.1. When all of the switching operations from the tests are considered as causing transients, 94% of the transients occurring on the 115 Vac buses had a peak voltage below 25V and 82% of the transients occurring on the 28 Vdc bus were below 0.5V. Most of the transients below the 25 Vac and 0.5 Vdc limits were not recorded and were not included as part of the data base. The statistical analysis considered only those transients in the data base as the total transients; therefore, the distribution percentages for transient amplitudes will be higher than stated in the results.

3.3. Waveforms. Data accumulated during the investigation indicated that the predominant waveform is a damped sinusoid. While all damped sinusoids recorded were similar in appearance, each exhibited its own characteristics (frequency, amplitude, "Q" etc.) based on the switching/source interruption and the natural resonance of the test platform (the aircraft) and associated power cabling.

3.3.1. For 115 Vac power, the damped sinusoidal waveform accounted for over 75%, 90%, and 65% of the total waveforms recorded during the ground phase, engine power phase, and APU power phase, respectively, from on-ground testing. Almost all of the in-flight test waveforms (99%) were the damped sinusoids. Analysis of the 28 Vdc waveshape data indicated, as shown in table V, that a high percentage of the transients recorded fell into the critically damped or over-damped sinusoidal waveform categories.

3.3.2. Statistical information derived from the waveshape data for the 28 Vdc bus is very similar to that for the 115 Vac bus. Damped sinusoidal waveforms accounted for over 90%, 96%, and 85% of all waveforms recorded during the ground power phase, engine power phase, and APU power phase, respectively, of the on-ground testing. The in-flight waveshape data indicated that nearly all of the waveforms recorded exhibited the damped sinusoidal waveform. As shown in table V, a high percentage of the transients fell into the category of critically damped or over-damped sinusoidal waveforms.

TABLE V. WAVEFORM DATA

| On Ground | | |
|---|---|---|
| | % Critically-Damped or Over-Damped Sinusoidals | |
| Power Source | AC Lines | DC Lines |
| External | 75 | 90 |
| APU | 65 | 85 |
| Engine | 90 | 96 |
| Aircraft Type | | |
| Jet | 80 | 86 |
| Helicopter | 83 | 90 |
| Turbo-prop | 67 | 83 |
| Flight Hour Age | | |
| <100 | 79 | 92 |
| 100-1000 | 75 | 86 |
| >1000 | 73 | 90 |
| In Flight | | |
| Engine | 99 | 99 |

3.3.3. A close examination of all of the waveform data accumulated during the program indicated that the damped sinusoidal waveform is the most predominant, being over 80 percent of all the waveforms recorded. The examination consisted of reviewing every waveform on a digital oscilloscope, expanding the time base for better resolution and removing those clearly not oscillatory (or damped) in nature from the original data base.

3.3.3.1. The waveform encountered correlates closely with those caused by electromagnetic pulses and lightning. Figures 4, 5, and 6 show the similarities. Although the source of excitation is different for all three situations, because the test platform (the aircraft) is physically the same, the responses associated with the natural resonance of the test platform and its internal cabling are similar. Figure 5 is from MIL-STD-462 (dated 6 August 1986) and figure 6 is from a draft advisory circular, "Protection of Aircraft Electrical/Electronic Systems Against the Indirect Effects of Lightning," prepared by SAE Committee AE46 (dated 4 February 1987).

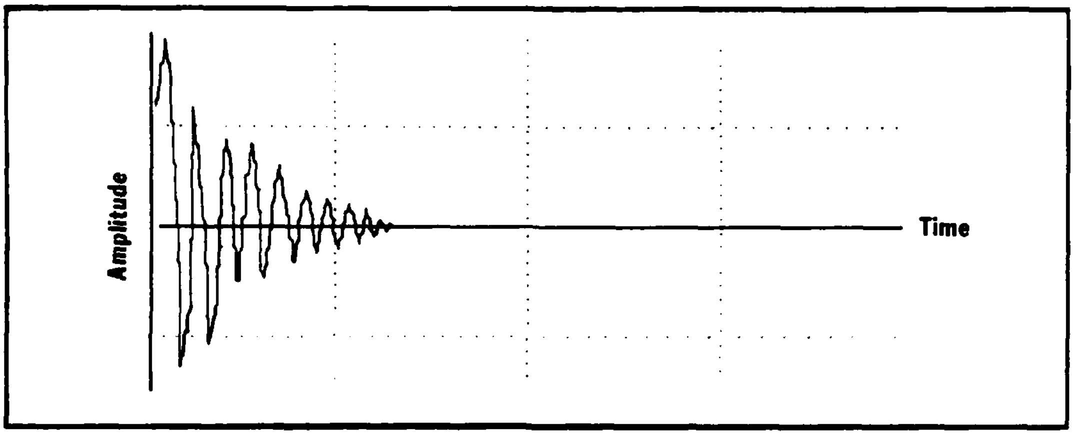



FIGURE 4. TYPICAL DAMPED SINUSOIDAL WAVEFORM FROM NESEA AIRCRAFT DATA

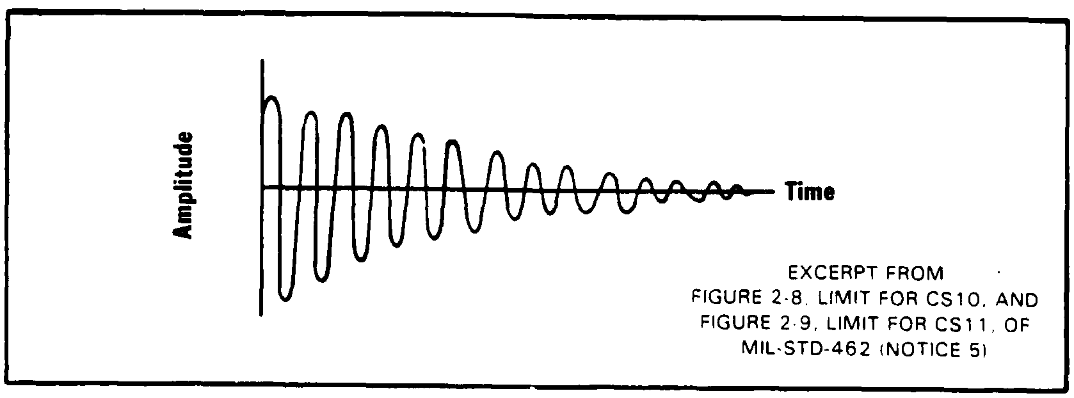



FIGURE 5. DAMPED SINUSOIDIAL WAVEFORM REQUIRED FOR EMP TEST METHODS CS10 AND CS11 OF MIL-STD-462 (NOTICE 5)

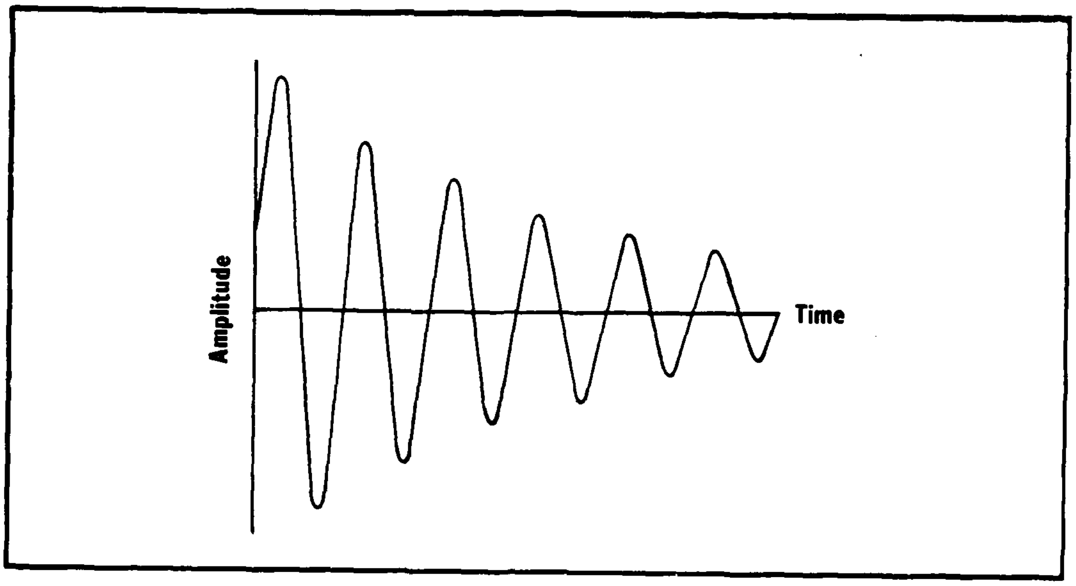



FIGURE 6. TYPICAL DAMPED SINUSOIDAL WAVEFORM INDUCED INTO AIRCRAFT POWERLINES BY LIGHTNING

3.3.3.2. As expected, because the length of each aircraft and its power cabling varies, the frequency distribution for the fundamental frequencies also varies. The data revealed a wide distribution of frequencies from approximately 1 to 10 MHz, corolating roughly to the length of the aircraft tested (approximately 30 to 300 feet) when fractional and multiple wavelength are considered.

3.3.3.3. When we examined waveform data to find a representative "Q", we determined that a good approximation was 6. "Q" is defined as follows:

$$Q = \frac{\pi (N-1)}{\ln \frac{V_1}{V_N}}$$

where

$\ln$ = natural log
$N$ = cycle number
$V_N$ = peak voltage of Nth cycle
$V_1$ = peak voltage of 1st cycle

3.3.3.4. Figure 7 shows how a 10 MHz continuous wave (CW) signal behaves in the frequency domain as the damping factor (Q) changes from 6 to 25. For a "Q" of 6, frequency components of significant amplitude are present for a 10 MHz damped sinusoidal waveform to at least 1.0 MHz. Similar traits can be expected for a damped CW signal of 1.0 MHz having a "Q" of 6.

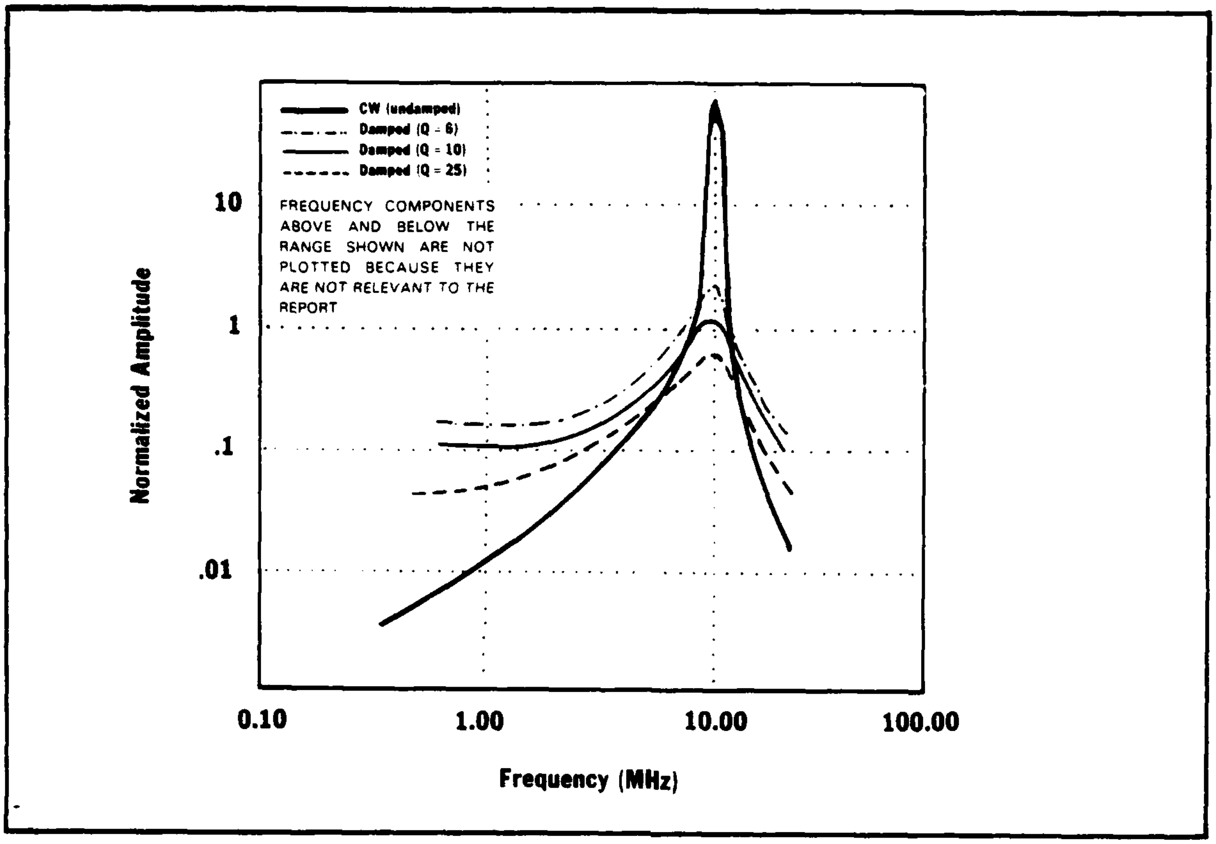



FIGURE 7. FAST FOURIER TRANSFORM OF 10 MHz SINUSOIDAL WAVEFORMS

3.3.3.5. Adding a new waveform as a test requirement would fill the void in the requirements for test method CS06 (Part 2, Aircraft) of MIL-STD-461. Two frequencies (1.0 and 10.0 MHz), damped with a "Q" of approximately 6, would be needed.

3.3.4. Unipolar pulses or critically damped pulses having a waveform shape similar to the test pulse waveform required by test method CS06 in MIL-STD-461B were recorded during the aircraft powerline transient tests. Only 59 transients from the 115 Vac 400 Hz bus data and only 107 transients from the 28 Vdc bus data were identified as having a unipolar waveshape (less than 50 microseconds duration). Only three unipolar pulses were recorded during the in-flight tests. The pulse width varied between 0.1 microsecond and 50 microseconds; however, 76% had pulse durations between 0.1 microsecond and 10 microseconds. Because the unipolar pulse appears on the power buses of aircraft in significant quantities, retaining the present CS06 pulse and its time duration requirements seems justified.

3.4. <u>Frequency</u>. The statistical analysis showed that a large number of powerline transients were distributed from 200 kHz to 8 MHz.

3.4.1. Frequency data were analyzed using the same categories as in the amplitude and waveform analysis. Only those transients that were clearly oscillatory and had amplitudes larger than the preset thresholds of 25V for 115 Vac power and 0.5V for 28 Vdc power were included. Because the frequency distribution was similar for all categories, the following paragraphs address the on-ground and in-flight test results.

3.4.1.1. Analysis of the on-ground test results showed that powerline transient frequencies were evenly distributed throughout the frequency range of 200 kHz to at least 3 MHz. Table VI shows the distribution of the largest number of transient frequencies compared with the total number of transients.

3.4.1.2. Analysis of the in-flight data showed that the transient frequencies were evenly distributed from approximately 200 kHz to at least 8 MHz on both the 115 Vac buses and the 28 Vdc buses.

TABLE VI. ON-GROUND TRANSIENT FREQUENCIES

| 115 Vac bus | | 28 Vdc bus | |
|---|---|---|---|
| Frequency (kHz) | Percentage | Frequency (kHz) | Percentage |
| 550-600 | 6 | 250-300 | 11 |
| 1400-1450 | 6 | 550-600 | 5 |
| 1450-1500 | 4 | 800-850 | 5 |
| 2150-2200 | 4 | 1500-1550 | 21 |
| 2450-2500 | 3 | | |
| 2800-2850 | 3 | | |

## 4. CONCLUSIONS.

4.1. On the ac powerline, all transients lasting less than 50 microseconds had peak amplitudes below 200V and approximately 70% were below 50V. On the dc line, all transients had amplitudes less than or equal to 24V and approximately 90% had less than 6V peak amplitude. (Para. 3.1.)

4.2. On-the-ground test conditions can be used to predict the amplitudes of transients occurring on the 115 Vac buses of aircraft in flight. (Para. 3.1.1.)

4.3. The 200V test spike required by MIL-STD-461B Test Method CS06 is excessive when applied to 28 Vdc lines. (Para. 3.1.2.)

4.4. Most (94%) of the transients on the 115 Vac bus had a peak voltage below 25V, and 82% on the 28 Vdc bus were below 0.5V. (Para. 3.2.1.)

4.5. Although damped sinusoidal waveforms were predominant, unipolar pulses occurred in significant quantities. (Paras. 3.3.1. and 3.3.4.)

4.6. MIL-STD-461 Test Method CS06 does not address test requirements for damped CW signals of 1.0 MHz and 10 MHz having a "Q" of 6. (Paras. 3.3.3.4. and 3.3.3.5.)

4.7. Powerline transients have fundamental frequencies from approximately 200 kHz to 8 MHz. (Paras. 3.4.1.1. and 3.4.1.2.).

## 5. RECOMMENDATIONS.

5.1. The amplitude of the MIL-STD-461 CS06 test spikes applied to equipment designed for 115 Vac 400 Hz operation should be retained at the present level of 200V peak. The amplitude requirement for equipment using the 28 Vdc power should be decreased to 24V peak. These requirements are for damped sinusoid pulses as well as unipolar pulses.

5.2. The present test waveform requirements of Test Method CS06 for unipolar pulses should be retained.

5.3. Two damped sinusoid waveforms should be added to the requirements for MIL-STD-461C Test Method CS06 (Part 2, Aircraft). The first should have a 10 MHz fundamental frequency and a "Q" of 6 and the second should have a fundamental frequency of 1 MHz and a "Q" of 6.

5.4. Test Method CS06 of MIL-STD-461C (Part 2, Aircraft) should be clarified to indicate that the requirements are for both ground and flight conditions.

5.5. The present requirements for Test CE07 of MIL-STD-461C (Part 2, Aircraft) should be retained.

APPENDIX A

REFERENCES

1. MIL-STD-461A, "Electromagnetic Interference Characteristics Requirements for Equipment."

2. MIL-STD-461B, "Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference."

3. MIL-STD-704A, "Electrical Power, Aircraft, Characteristics and Utilization of."

4. MIL-STD-704D, "Aircraft Electrical Power Characteristics."

5. MIL-STD-6051D, "Electromagnetic Compatibility Requirements (for) Systems."

6. Radio Technical Commission for Aeronautics Report DO-160A, "Environmental Conditions and Test Procedures for Airborne Equipment."

7. R&B Enterprises Report No. 871704, "Aircraft Powerline Transient Data Analysis," 31 March 1987.

8. Naval Electronic Systems Engineering Activity (NESEA) Report on "Investigation of Powerline Transients on Type HU-25A Aircraft," 25 April 1985.

9. NESEA Report on "Investigation of Powerline Transients on Type TF-18A Aircraft," 30 August 1985.

10. NESEA Report on "Investigation of Powerline Transients on Type RP-3D Aircraft," 11 March 1986.

11. NESEA Report on "Investigation of Powerline Transients on Type ATF-2 Aircraft," 6 January 1986.

12. NESEA Report on "Investigation of Powerline Transients on Type HU-65A Aircraft," 4 April 1986.

13. NESEA Report on "Investigation of Powerline Transients on Type HH-3F Aircraft," 30 May 1986.

14. NESEA Report on "Investigation of Powerline Transients on Type AV-8B Aircraft," 1 July 1986.

15. NESEA Report on "Investigation of Powerline Transients on Type HC-130H Aircraft," 11 July 1986.

16. NESEA Report on "Aircraft Powerline Transients Investigation (In-flight)," 15 June 1987.

# APPENDIX B
# DESCRIPTIONS OF TEST AIRCRAFT

1. A-7E AIRCRAFT.

1.1. General Characteristics. The A-7E Corsair II is a single-place, carrier/land-based, light attack aircraft which incorporates advanced radar, navigation, and weapons delivery systems. See figure 1.

1.2. Historical Data. the first model of the A-7 type aircraft was produced in 1965 and the first A-7E model was delivered in 1968. The aircraft under investigation, BUNO 160887, was produced in February 1981 and, at the time of testing, 22 November 1982, had logged 1,027 flight hours.

2. UH-1N AIRCRAFT.

2.1. General Characteristics. The U.S. Navy Series UH-1N utility helicopter is manufactured by Bell Helicopter Textron. It is capable of operating from prepared or unprepared takeoff and landing areas, under visual flight rule (VFR) or instrument flight rule (IFR) conditions, day or night. Designed for cargo-passenger service, the UH-1N can accommodate passengers or be configured for medical evacuation and ambulance service carrying six patients and one medical technician. See figure 2.

2.2. Historical Data. The first model of the H-1 type aircraft was produced in 1956, and the first UH-1N model was delivered in May 1971. The aircraft under investigation, BUNO 160624, was produced on 4 April 1978 and, at the time of testing, 26 January 1983, had logged 640 flight hours.

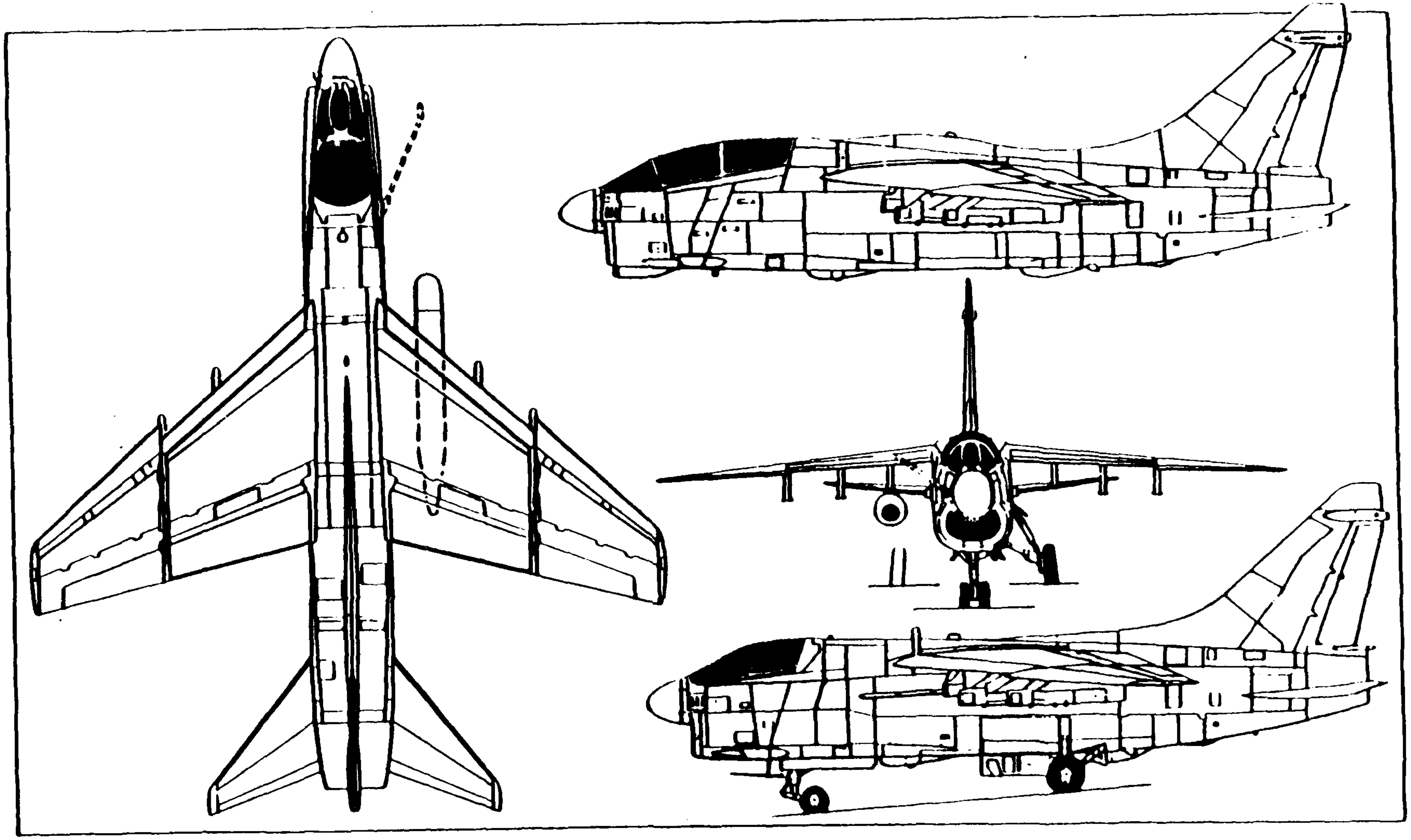
3. P-3C AIRCRAFT.

3.1. General Characteristics. The P-3C (see figure 3) is a four-engine, land-based, low-winged aircraft used by the U.S. Navy for antisubmarine warfare patrols. The aircraft has advanced submarine detection equipment including a computer to interface the detection, ordnance, and armament systems. Other distinct features include a sophisticated communications system and a satellite global positioning system.

3.2. Historical Data. The first P-3 aircraft was produced in November 1959, and the first P-3C model was delivered in September 1968. The aircraft under investigation, BUNO 161415, was produced in January 1983 and, at the time of testing, 21 March 1983, had logged 45 flight hours.

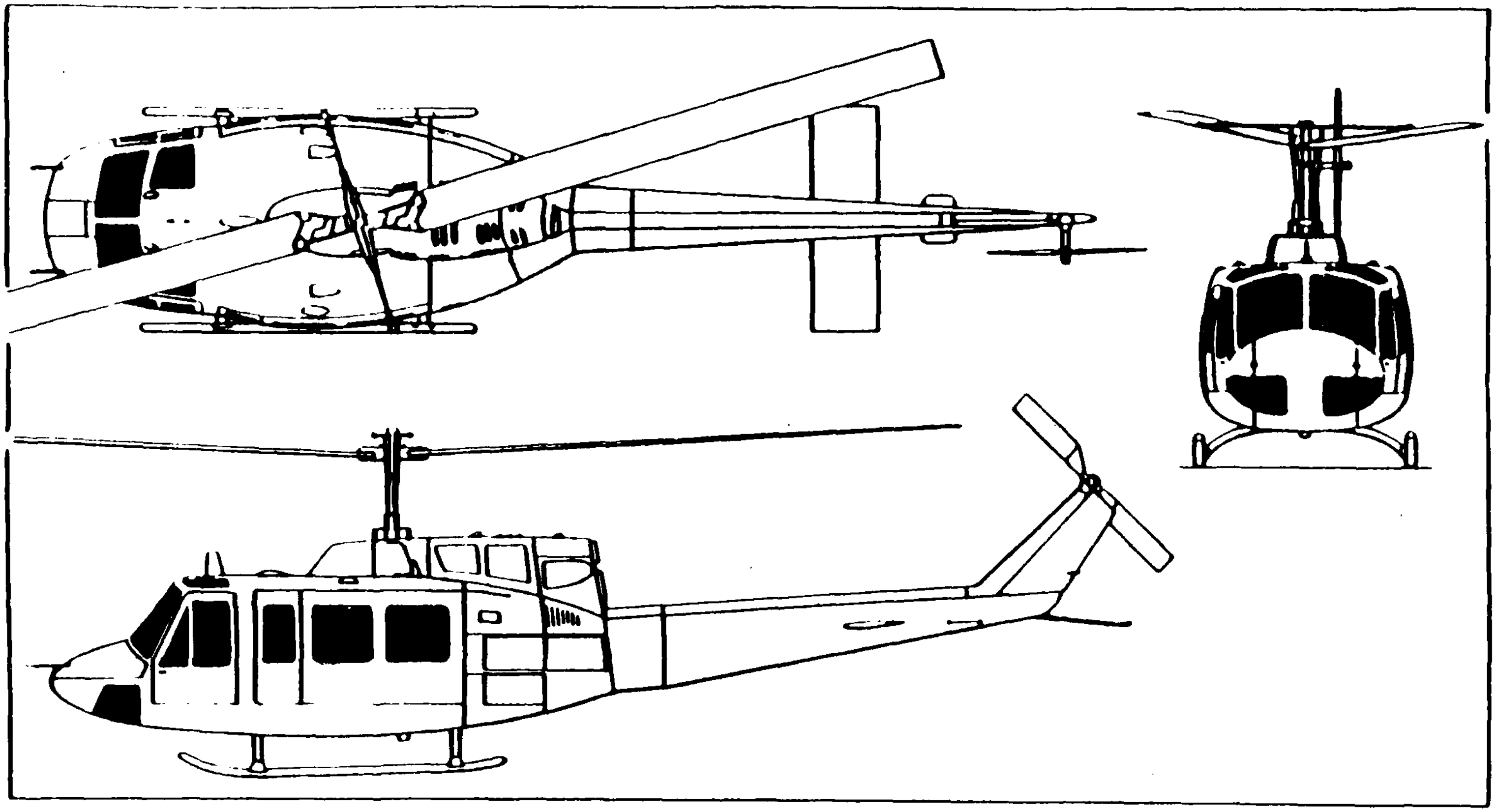
4. CH-46E AIRCRAFT.

4.1. General Characteristics. The CH-46E Sea Knight is a twin-turbine powered, dual-piloted, tandem-rotor helicopter, designed by The Boeing Vertol Company. The primary mission of the CH-46E is to transport combat troops, support equipment, and supplies



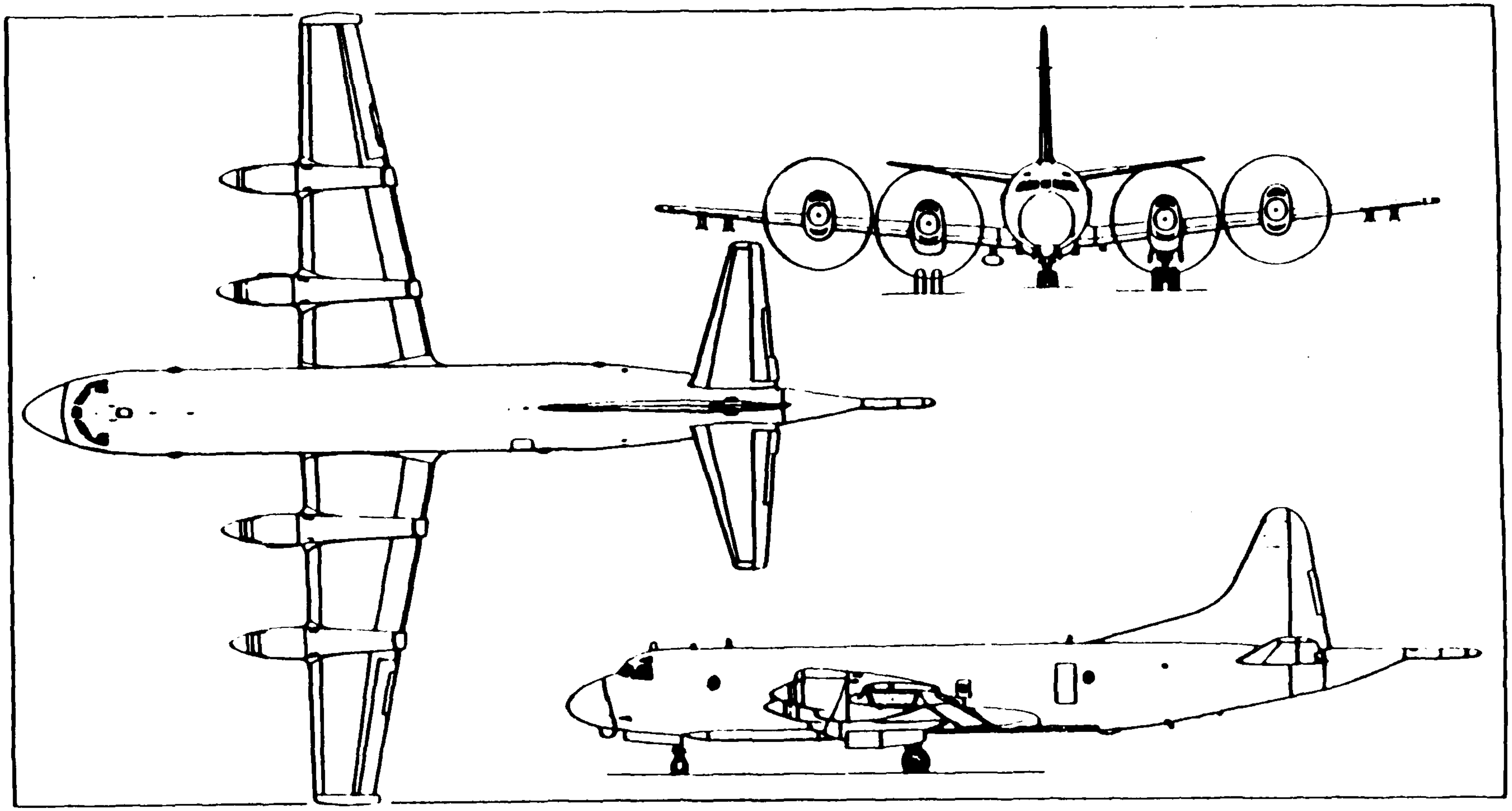
| | |
|---|---|
| Wing span | 11.80 m (38 ft 9 in) |
| Width, wings folded | 7.24 m (23 ft 9 in) |
| Length overall | 14.06 m (46 ft 1½ in) |
| Height overall | 4.90 m (16 ft 0¾ in) |
| Tailplane span | 5.52 m (18 ft 1½ in) |

Figure 1: A-7E



| | |
|---|---|
| Main rotor diameter (with tracking tips) | 14.69 m (48 ft 2¼ in) |
| Tail rotor diameter | 2.59 m (8 ft 6 in) |
| Length overall (main rotor fore and aft) | 17.46 m (57 ft 3¼ in) |
| Length of fuselage | 12.92 m (42 ft 4¾ in) |
| Height overall | 4.53 m (14 ft 10¼ in) |
| Width overall (main rotor fore and aft | 2.86 m (9 ft 4½ in) |

Figure 2: UH-1N



| | |
|---|---|
| Wing span | 30.37 m (99 ft 8 in) |
| Length overall | 35.61 m (116 ft 10 in) |
| Height overall | 10.27 m (33 ft 8½ in) |
| Tailplane span | 13.06 m (42 ft 10 in) |
| Propeller diameter | 4.11 m (13 ft 6 in) |

Figure 3: P-3C

rapidly from amphibious assault landing ships and established airfields to advance bases in underdeveloped areas having limited maintenance and logistic support. The CH-46E operates in all weather conditions, day or night. Figure 4 shows the aircraft.

4.2. Historical Data. The first model of the H-46 type aircraft was produced in 1962. The aircraft underwent several modifications and in 1966 the CH-46D was produced. In January 1977 the CH-46Ds were converted to CH-46Es. The aircraft under investigation, BUNO 153372, was produced in March 1968, converted in August 1978 to a CH-46E and, at the time of testing, September 1983, had logged 2,624 flight hours.

5. HU-25A AIRCRAFT.

5.1. General Characteristics. The U.S. Coast Guard HU-25A is a land-based, twin-jet aircraft. It is an extensively modified version of the commercially available "Falcon" business jet that has been adapted for air/sea search and rescue, law enforcement, marine environmental protection, marine science activities, and mission support operations. See figure 5.

5.2. Historical Data. The first model of the HU-25A was produced in November 1977 and the first aircraft was delivered to the Coast Guard on 19 February 1982. The aircraft under investigation, CGNR 2110, was produced on 30 April 1982 and, at the time of testing, 18 June 1984, had logged 689 flight hours.

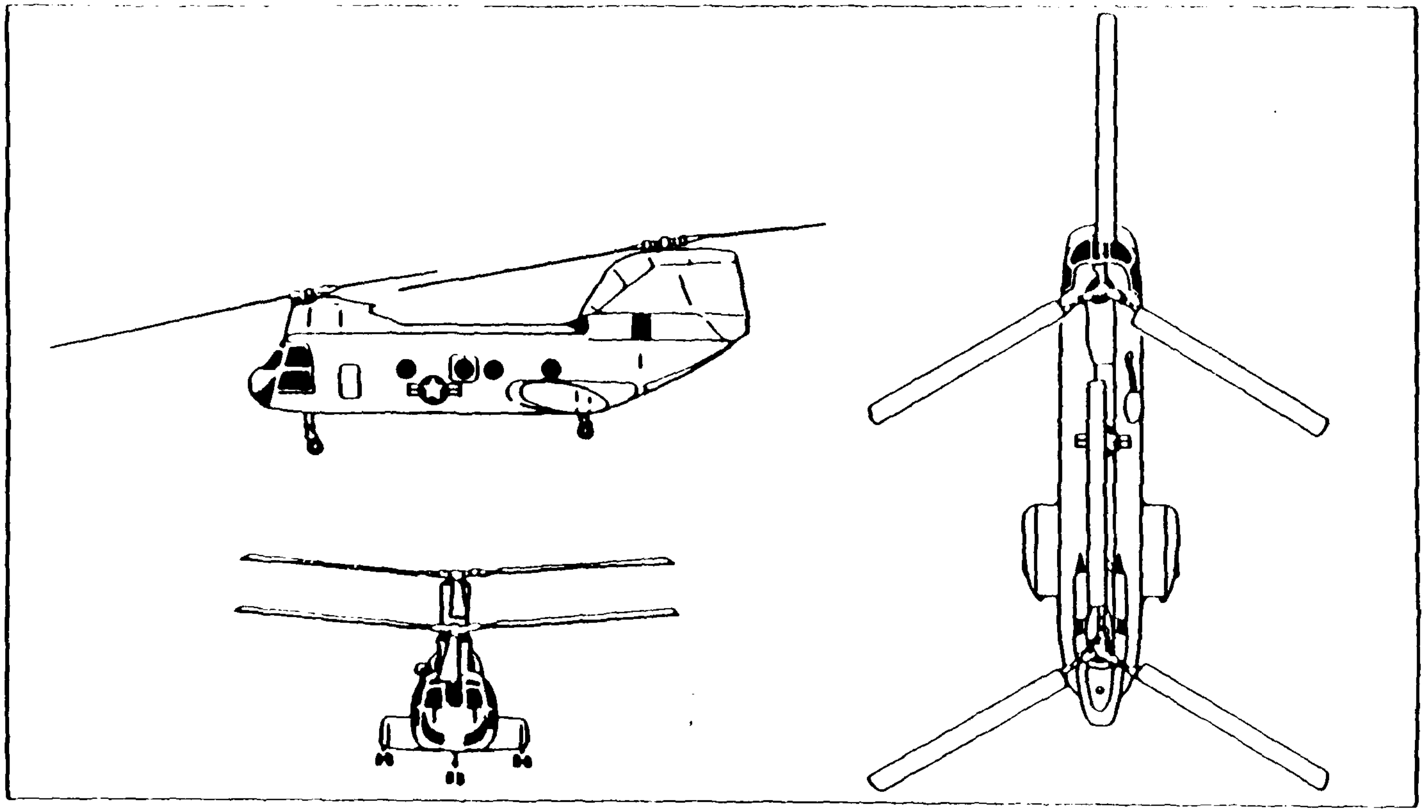
6. CH-46E (SR&M) AIRCRAFT.

6.1. General Characteristics. The CH-46E (SR&M) Sea Knight is a twin-turbine powered, dual-piloted, tandem-rotor helicopter, designed by The Boeing Vertol Company. The mission of the CH-46E (SR&M) is the same as that of the CH-46E (no SR&M). It too is an all-weather aircraft. See figure 6.

6.2. Historical Data. The first model of the H-46 type aircraft was produced in 1962. The aircraft underwent several modifications and in 1966 the CH-46D was produced. In January of 1977 the CH-46Ds were converted to CH-46Es. The CH-46E (SR&M) aircraft, BUNO 153362, was produced in August 1967, converted in October 1978 and again converted for SR&M in March 1985. At the time of testing, 31 July 1984, it had logged 4,692 flight hours.

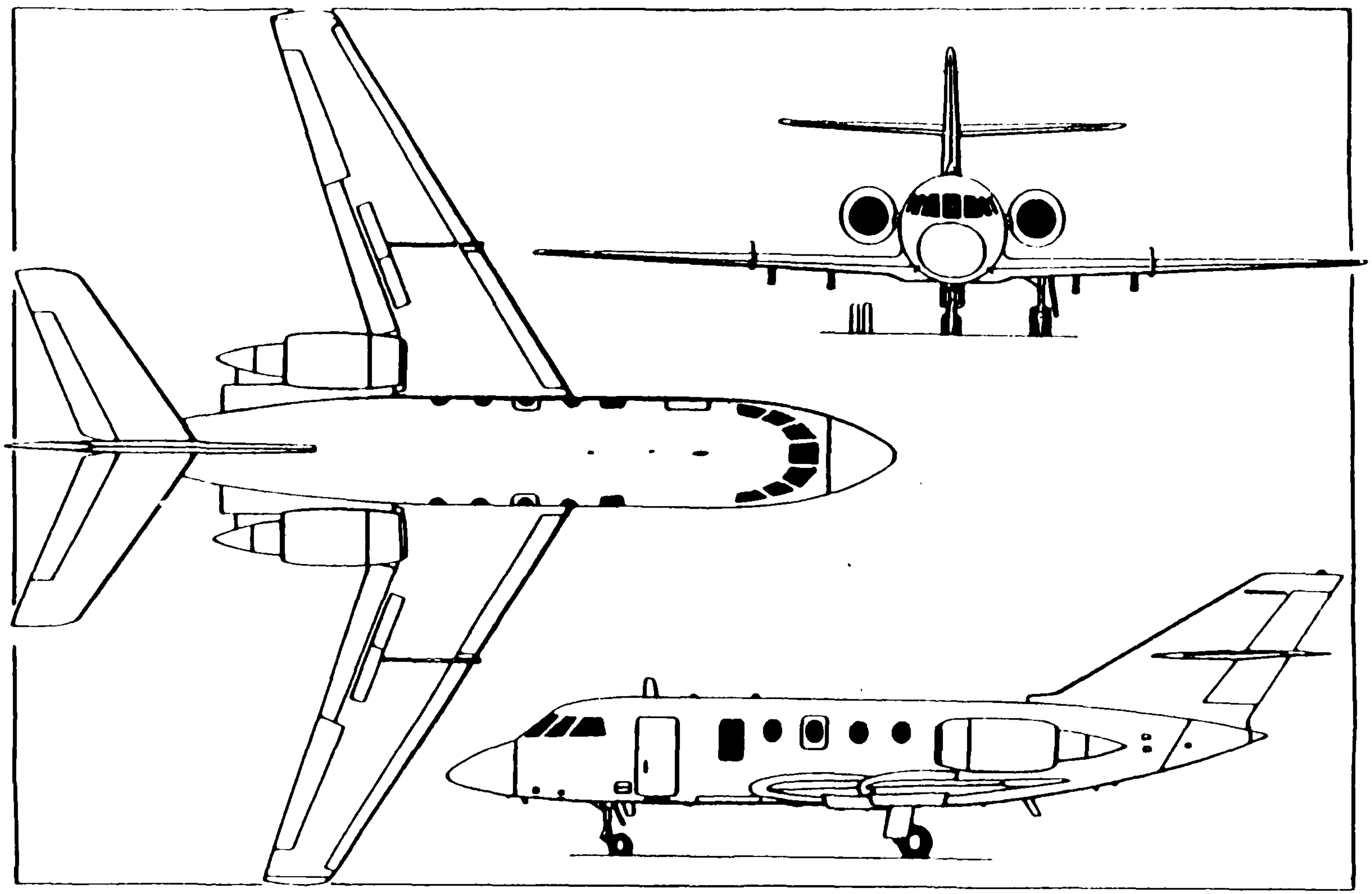
7. TF-18A AIRCRAFT.

7.1. General Characteristics. The TF-18A aircraft (see figure 7) is a two-place training version of the F-18A "Hornet" single-place fighter/attack aircraft (carrier-based) built by McDonnell Douglas Aircraft Company.



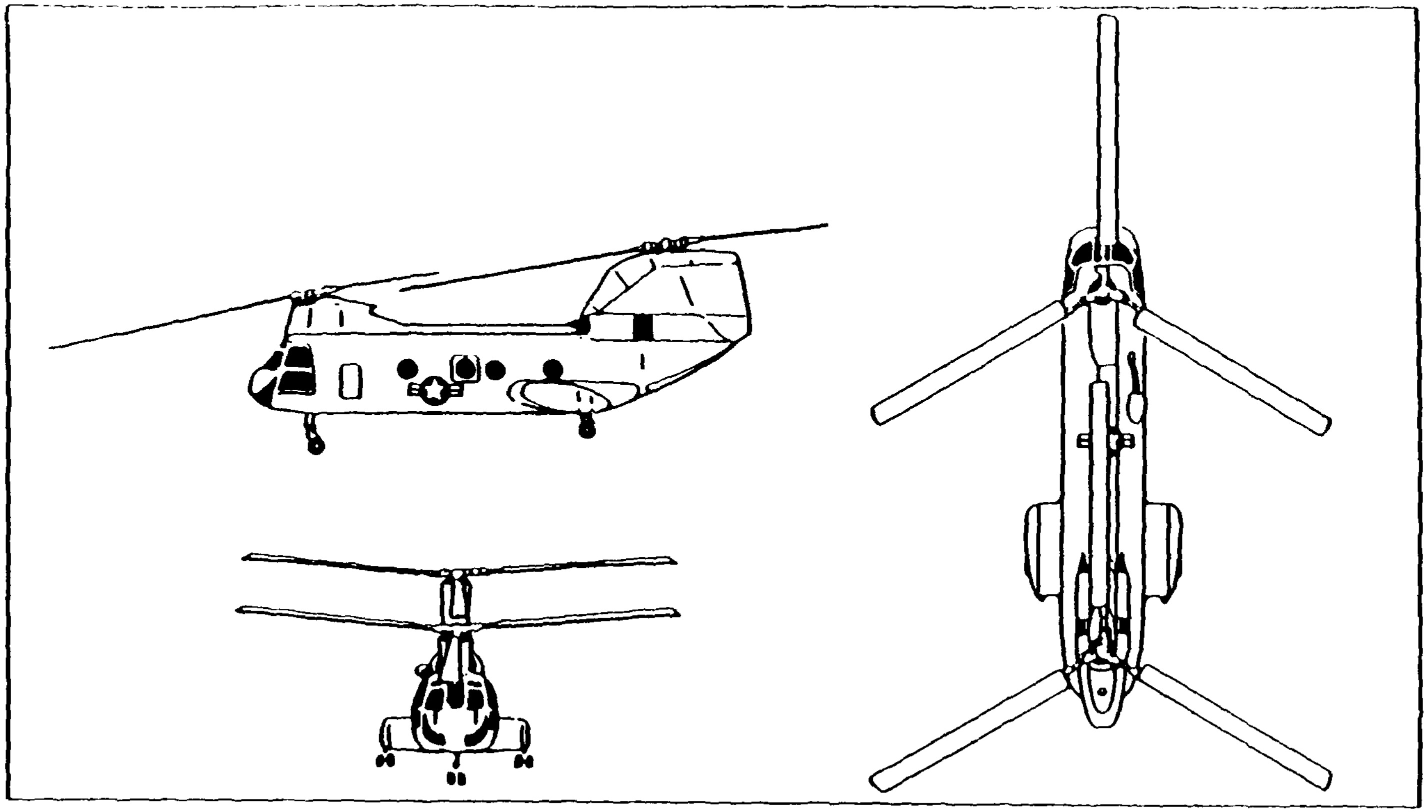
| | |
|---|---|
| Rotor diameter (each) | 15.24 m (50 ft 0 in) |
| Length overall, both rotors turning | 25.40 m (83 ft 4 in) |
| Length of fuselage | 13.59 m (44 ft 7 in) |
| Height to top of rear rotor head | 5.13 m (16 ft 10 in) |
| Width over mainwheels | 4.42 m (14 ft 6 in) |

Figure 4: CH-46E



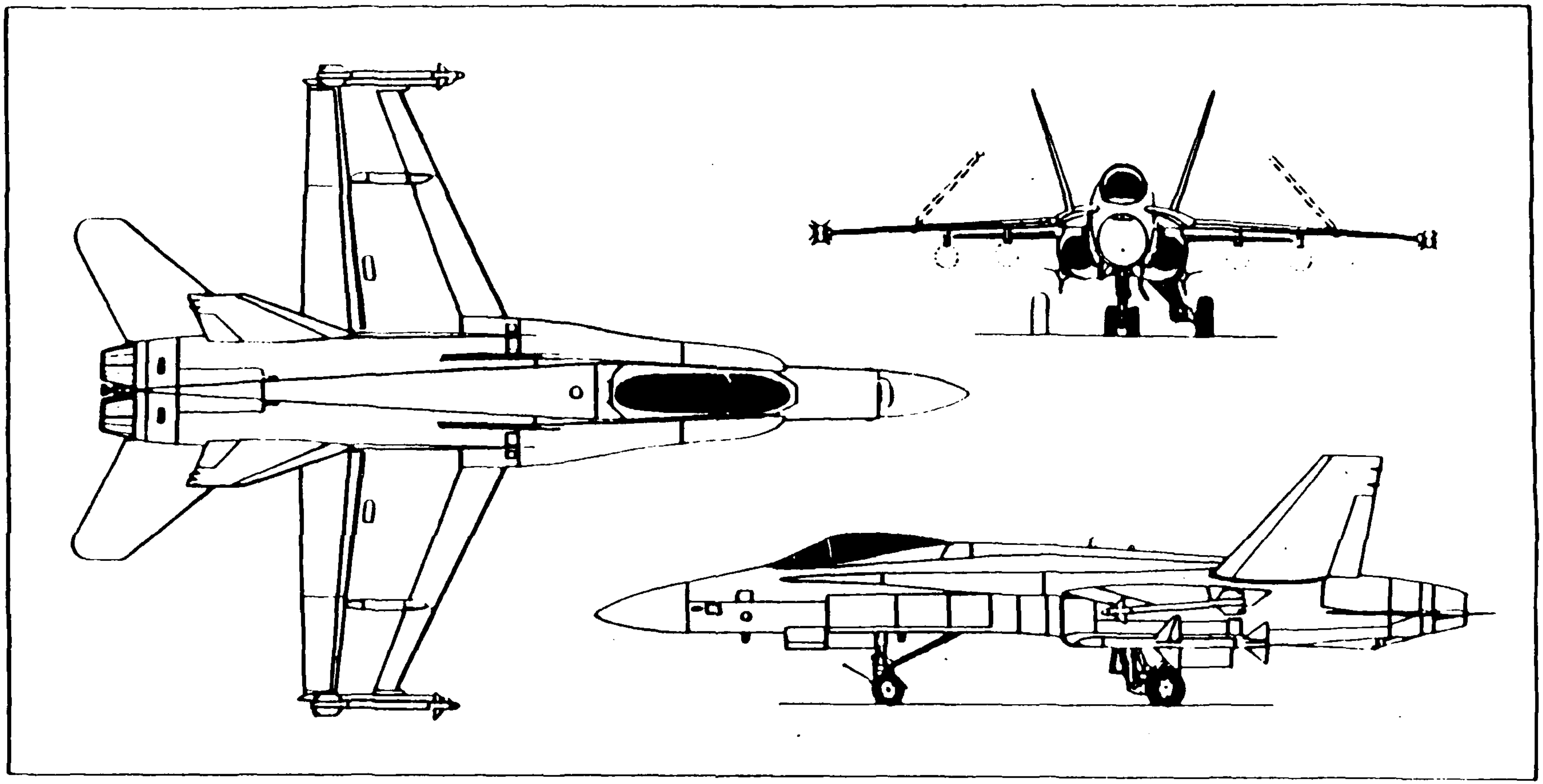
| | |
|---|---|
| Wing span | 16.30 m (53 ft 6 in) |
| Length overall | 17.15 m (56 ft 3 in) |
| Height overall | 5.32 m (17 ft 5 in) |
| Tailplane span | 6.74 m (33 ft 1 in) |

Figure 5: HU-25A



| | |
|---|---|
| Rotor diameter (each) | 15.24 m (50 ft 0 in) |
| Length overall, both rotors turning | 25.40 m (83 ft 4 in) |
| Length of fuselage | 13.59 m (44 ft 7 in) |
| Height to top of rear rotor head | 5.13 m (16 ft 10 in) |
| Width over mainwheels | 4.42 m (14 ft 6 in) |

Figure 6: CH-46E (SR&M)



| | |
|---|---|
| Wing span | 11.43 m (37 ft 6 in) |
| Width, wings folded | 8.38 m (27 ft 6 in) |
| Length overall | 17.07 m (56 ft 0 in) |
| Height overall | 4.66 m (15 ft 3½ in) |
| Tailplane span | 6.58 m (21 ft 7¼ in) |

Figure 7: TF-18A

7.2. Historical Data. The first model of the F/A-18 type aircraft was produced in 1978, and the first model was delivered in 1981. The TF-18A is a training version of the F/A-18 and the aircraft under investigation, BUNO 161714, was produced in February 1981. At the time of testing, 13 December 1984, it had logged 814 flight hours.

8. RP-3D AIRCRAFT.

8.1. General Characteristics. The RP-3D aircraft is a four-engine, land-based, extensively modified P-3C aircraft used by the U.S. Naval Oceanographic Office. It was modified to conduct airborne geomagnetic surveys of the ocean. Its primary distinguishable feature is a demagnetized area in the rear of the aircraft with mounting provisions for a neutron monitor, a ridged support beam to mount two gyroscope assemblies for the inertial systems, and a vector airborn magnetometer. Other distinct features include a sophisticated communications system and a satellite global positioning system. Figure 8 shows the RP-3D.

8.2. Historical Data. The first model of the P-3 type aircraft was produced in November 1959 and the "C" model was delivered in September 1968. The RP-3D model (BUNO 158227), a one-of-a-kind aircraft, was delivered in November 1971. At the time of testing, 10 April 1985, it had logged 11,712 flight hours.

9. HH-65A AIRCRAFT.

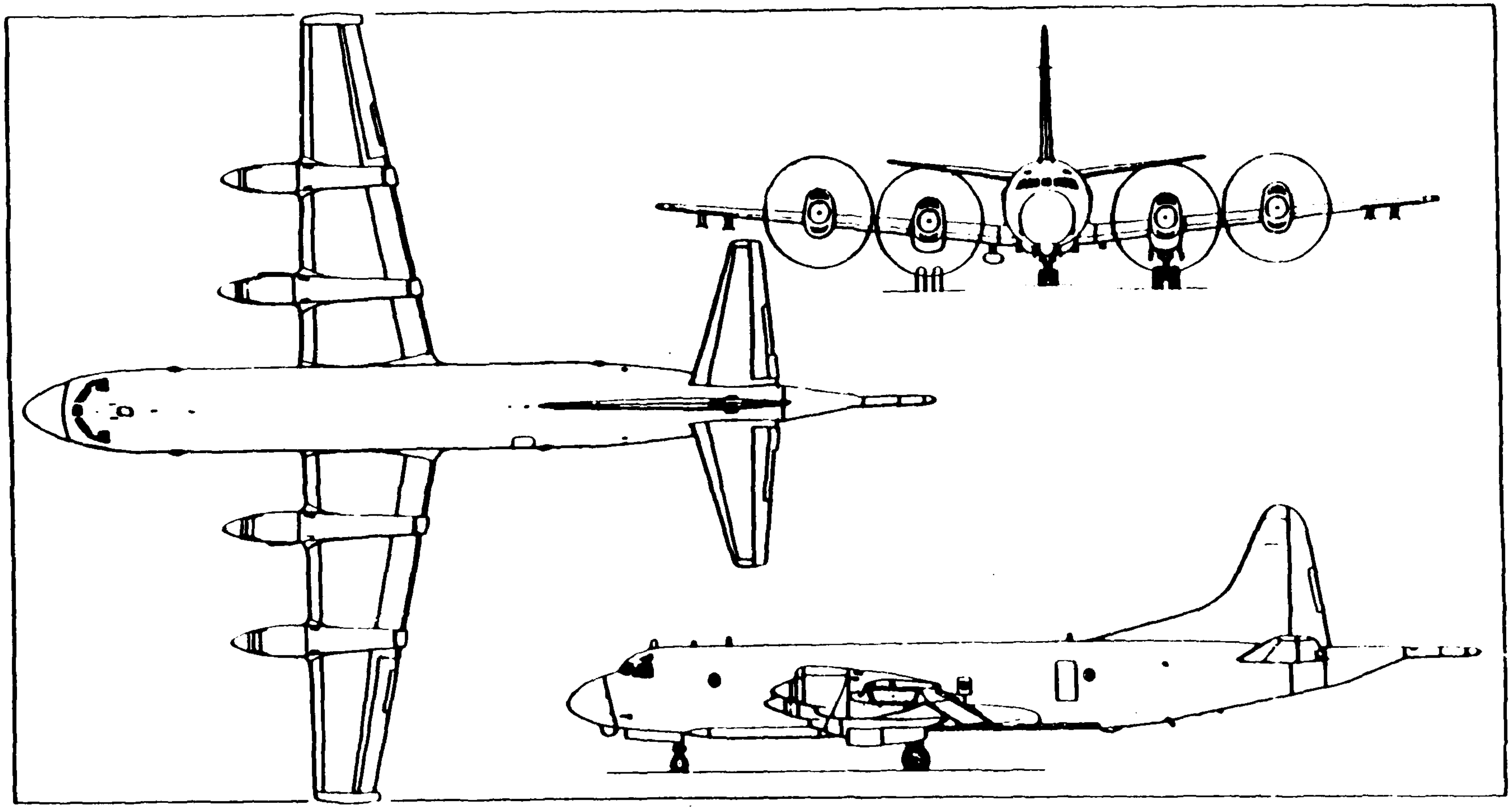
9.1. General Characteristics. The U.S. Coast Guard HH-65A helicopter was built by Aerospatiale Helicopter Corp. It is designed as a short-range search and rescue, patrol, observation passenger transport, and cargo hook operational aircraft. See figure 9.

9.2. Historical Data. The first model, the HH-65A, was produced in July 1980 and delivered to the Coast Guard in July 1982. The aircraft under investigation, CGNR 6506, was produced on 8 June 1985 and, at the time of testing, 9 September 1985, had logged 82 flight hours.

10. ATF-2 AIRCRAFT.

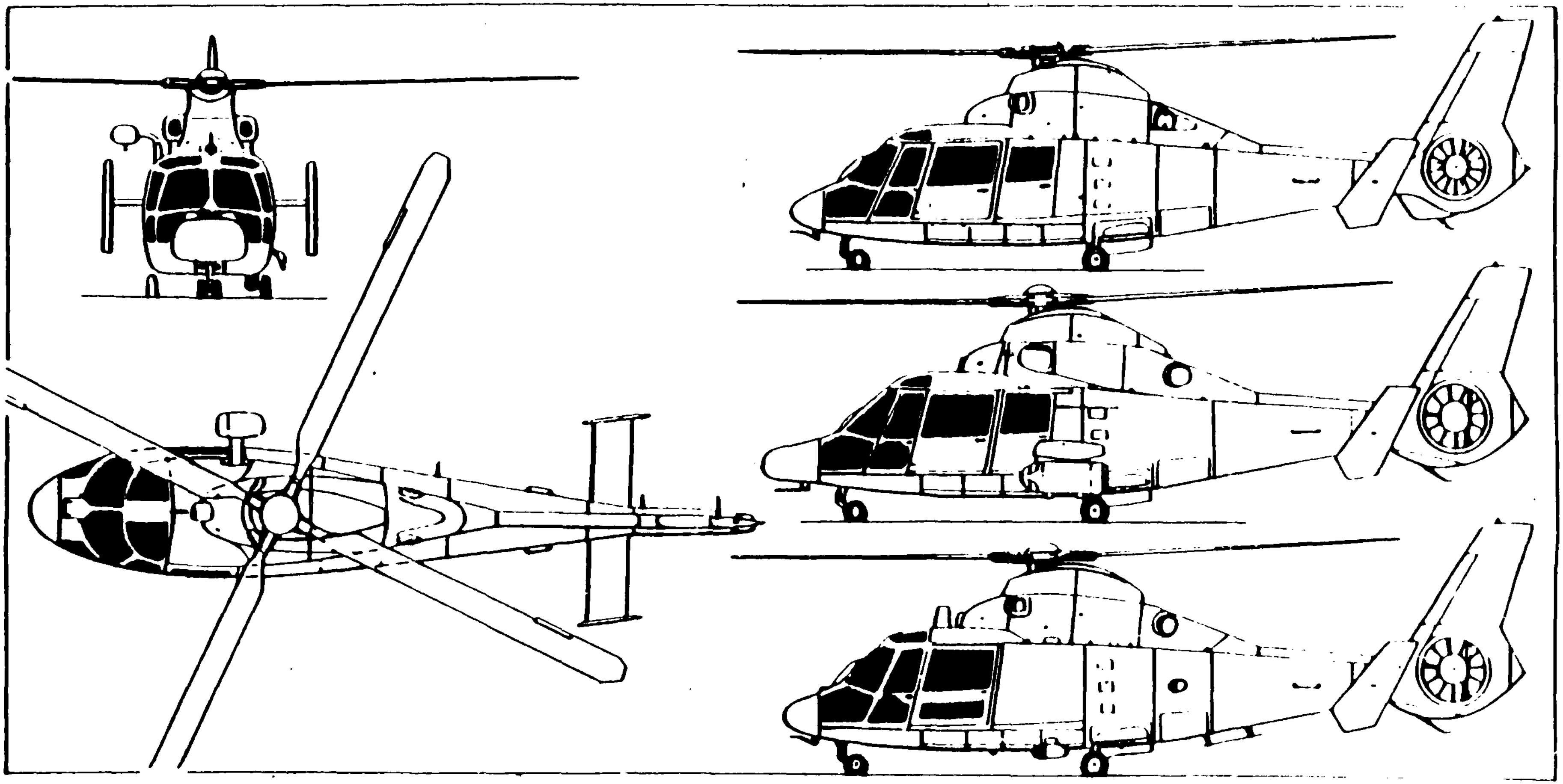
10.1. General Characteristics. The ATF-2 aircraft (see figure 10) is a two-place training version of the F-18A "Hornet" single-place fighter/attack aircraft (carrier-based) built by McDonnell Douglas Aircraft Company.

10.2. Historical Data. The first F/A-18 was produced in 1978 and delivered in 1981. The TF-18A is a training version of the F/A-18 and the ATF-2 is an Australian version of the TF-18A. The aircraft under test, ATF-2/102, was produced in August 1984 and, at the time of testing, 3 April 1985, had logged 14 flight hours.



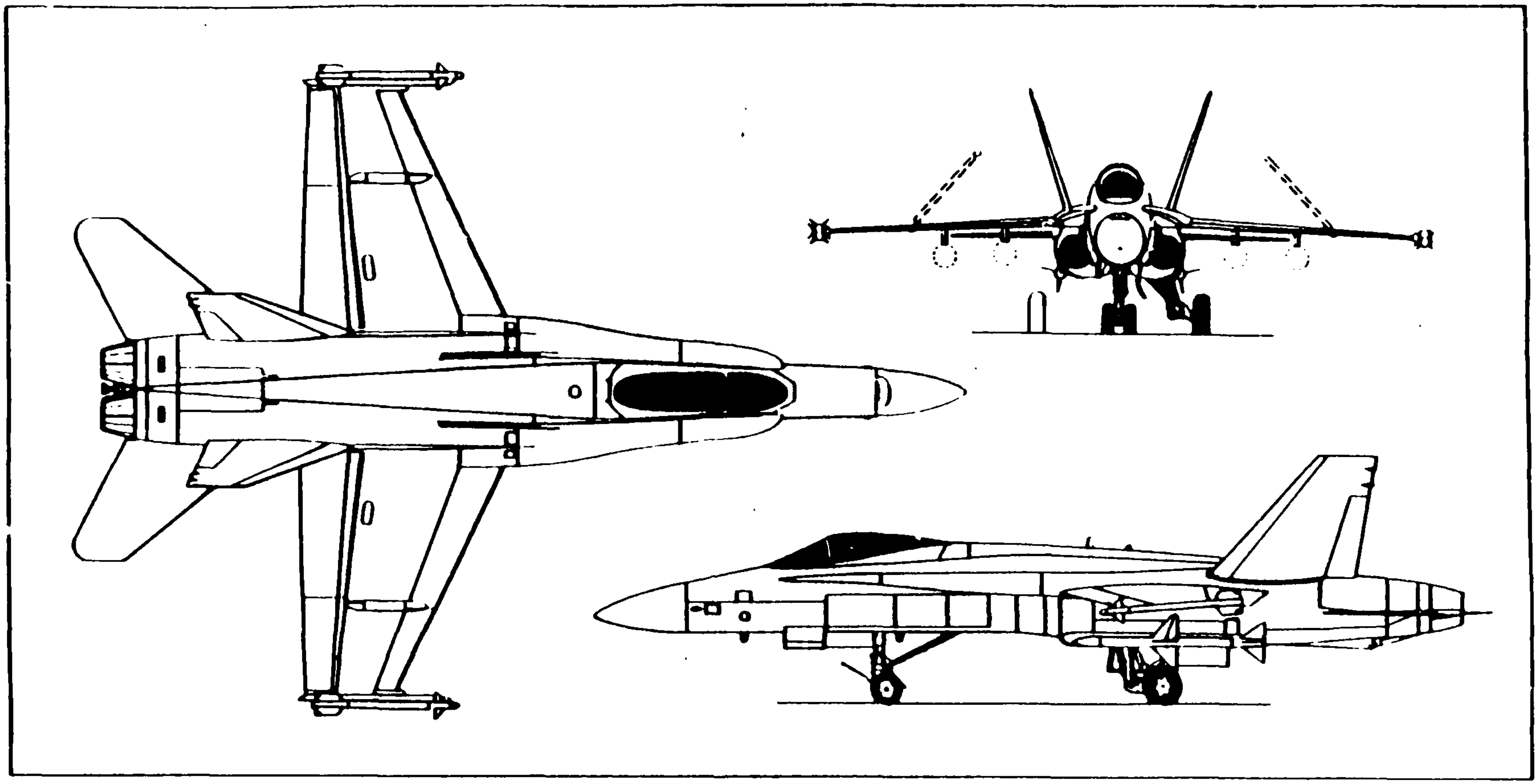
| | |
|---|---|
| Wing span | 30.37 m (99 ft 8 in) |
| Length overall | 35.61 m (116 ft 10 in) |
| Height overall | 10.27 m (33 ft 8½ in) |
| Tailplane span | 13.06 m (42 ft 10 in) |
| Propeller diameter | 4.11 m (13 ft 6 in) |

Figure 8: RP-3D



| | |
|---|---|
| Main rotor diameter | 11.93 m (39 ft 1¾ in) |
| Diameter of "fenestron" | 0.90 m (2 ft 11 7/16 in) |
| Length overall, rotor turning | 13.46 m (44 ft 2 in) |
| Length of fuselage | 11.44 m (37 ft 6½ in) |
| Height overall (tip of fin) | 4.01 m (13 ft 2 in) |

Figure 9: HH-65A



| | |
|---|---|
| Wing span | 11.43 m (37 ft 6 in) |
| Width, wings folded | 8.38 m (27 ft 6 in) |
| Length overall | 17.07 m (56 ft 0 in) |
| Height overall | 4.66 m (15 ft 3½ in) |
| Tailplane span | 6.58 m (21 ft 7¼ in) |

Figure 10: ATF-2

11. AV-8B AIRCRAFT.

11.1 General Characteristics. The AV-8B is a single-seat, single-engine, vertical short takeoff and landing (V/STOL) jet aircraft (carrier-based) designed for day/night operations involving close air support, intermediate range intercept, and attack missions. See figure 11.

11.2. Historical Data. The first model, the YAV-8, was produced in 1978, and the first AV-8B model was delivered in November 1981. The aircraft under investigation, BUNO 161576, was produced in June 1984 and, at the time of testing, 31 October 1985, had logged 24 flight hours.

12. HH-3F AIRCRAFT.

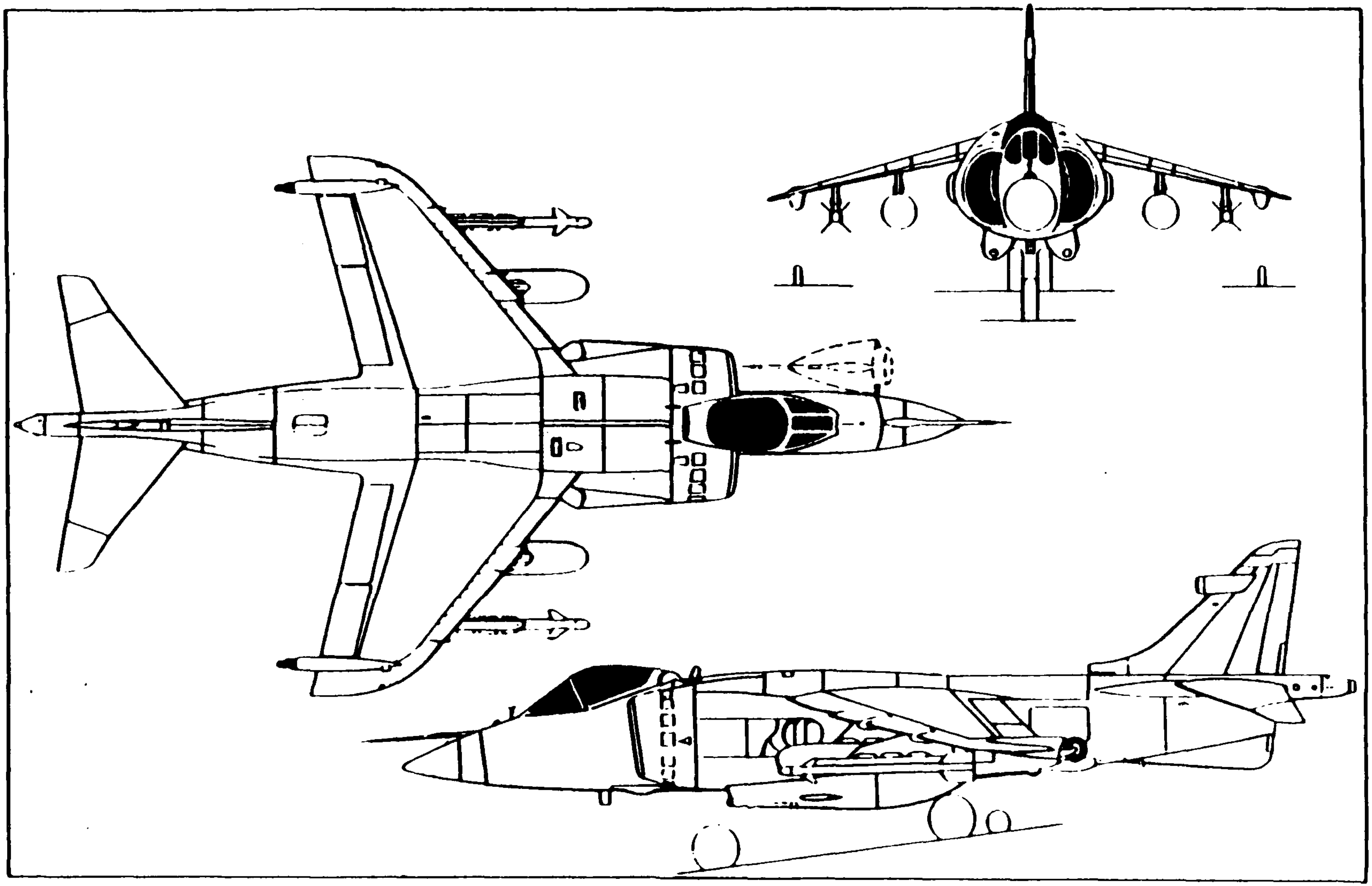
12.1. General Characteristics. The HH-3F (figure 12) is a medium-size, two-engine helicopter used by the U.S. Coast Guard to locate, recover, and assist people in distress. In addition, it may be used for logistic support, reconnaissance, and general utility. It usually carries a crew of four and can accommodate six additional passengers.

12.2. Historical Data. The first model of the H-3 was produced in 1967 and the first HH-3F was delivered to the Coast Guard in 1969. The aircraft under investigation, CGNR 1470, was produced in May 1969 and, at the time of testing, 16 September 1985, had logged 10,134 flight hours.

13. HC-130H AIRCRAFT.

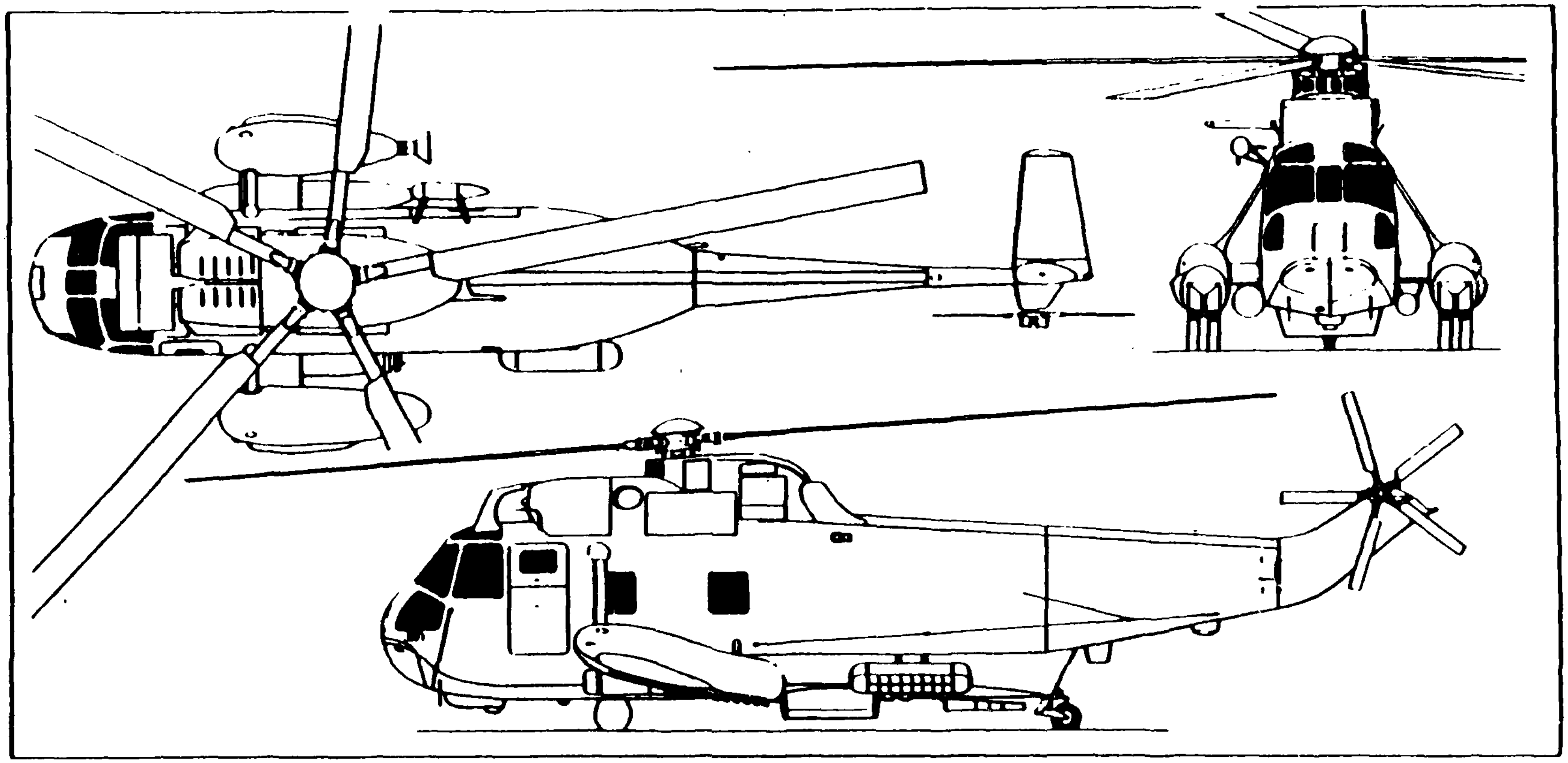
13.1. General Characteristics. The U.S. Coast Guard HC-130H shown in figure 13 is a four-engine, land-based aircraft, primarily designed for long-range search and rescue, patrol, observation, and passenger/material transportation.

13.2. Historical Data. The first C-130 was produced in September 1952 and the first HC-130H model was delivered to the Coast Guard in April 1975. The aircraft under investigation, CGNR 1713, was produced in November 1985 and, at the time of testing, 9 December 1985, had logged 10 flight hours.



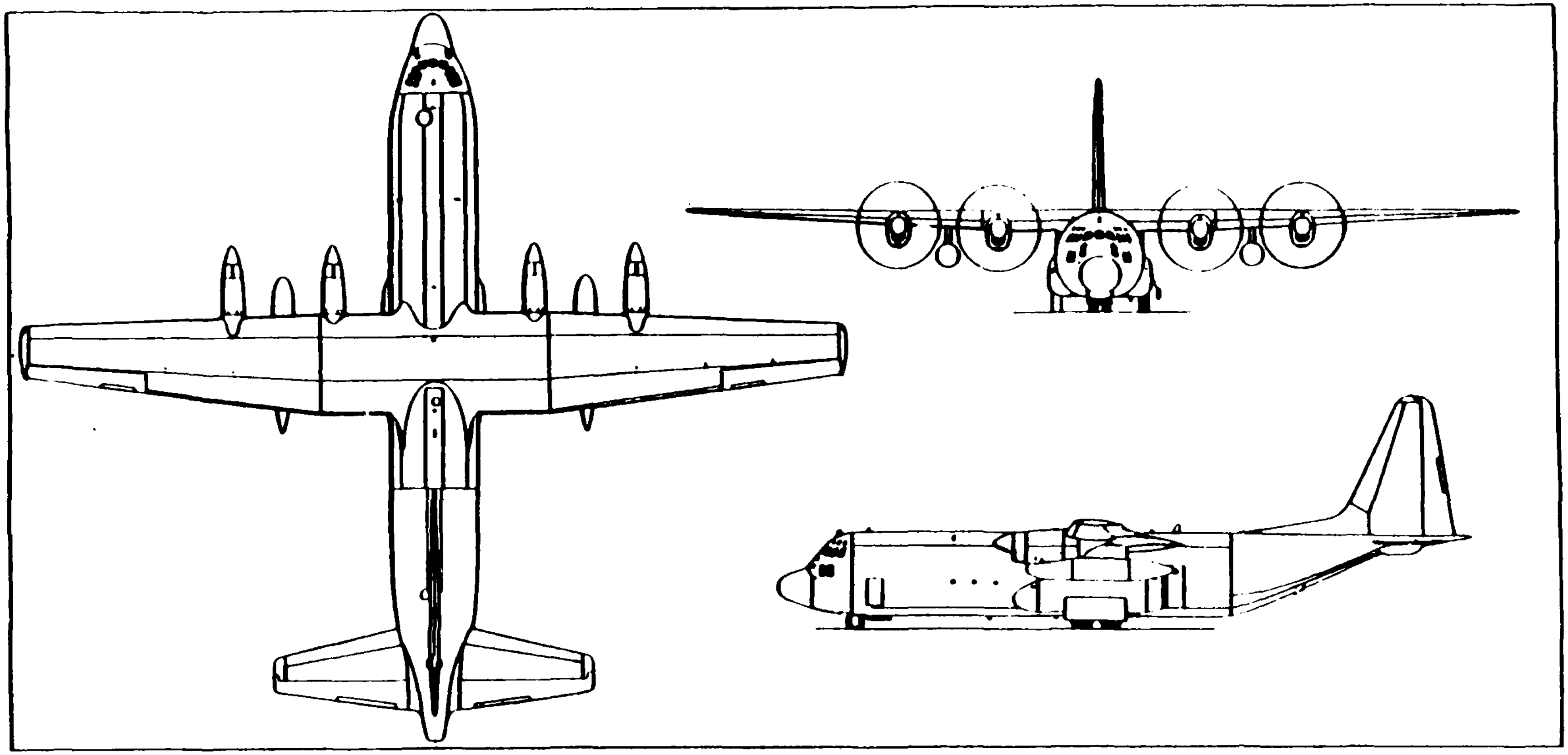
| | |
|---|---|
| Wing span | 9.25 m (30 ft 4 in) |
| Length overall (flying attitude) | 14.12 m (46 ft 4 in) |
| Height overall | 3.55 m (11 ft 7¾ in) |
| Tailplane span | 4.24 m (13 ft 11 in) |

Figure 11: AV-8B



| | |
|---|---|
| Main rotor diameter | 18.90 m (62 ft 0 in) |
| Tail rotor diameter | 3.16 m (10 ft 4 in) |
| Length overall, excluding radome | 22.26 m (73 ft 0 in) |
| Length of fuselage | 17.46 m (57 ft 3 in) |
| Width over landing gear | 4.82 m (15 ft 10 in) |
| Height overall | 5.51 m (18 ft 1 in) |

Figure 12: HH-3F



| | |
|---|---|
| Wing span | 40.41 m (132 ft 7 in) |
| Length overall | 34.37 m (112 ft 9 in) |
| Height overall | 11.66 m (38 ft 3 in) |
| Tailplane span | 16.05 m (52 ft 8 in) |
| Propeller diameter | 4.11 m (13 ft 6 in) |

Figure 13: HC-130H

# APPENDIX C

# TEST CONFIGURATION FOR EACH TEST AIRCRAFT

1. INTRODUCTION.

1.1. Because of differences in the electrical system of each test aircraft, slightly different test configurations and monitor points were used during the on-ground tests. The goal, however, was to choose a monitor point where all switching transients occurring within the aircraft could be recorded. Figures 1 through 12 show the monitor points and test configurations used during the on-ground tests for each aircraft except the A-7E which was not available but is similar to the other jet aircraft tested.

1.2. The test configurations used for the in-flight tests were similar to those for the on-ground tests.

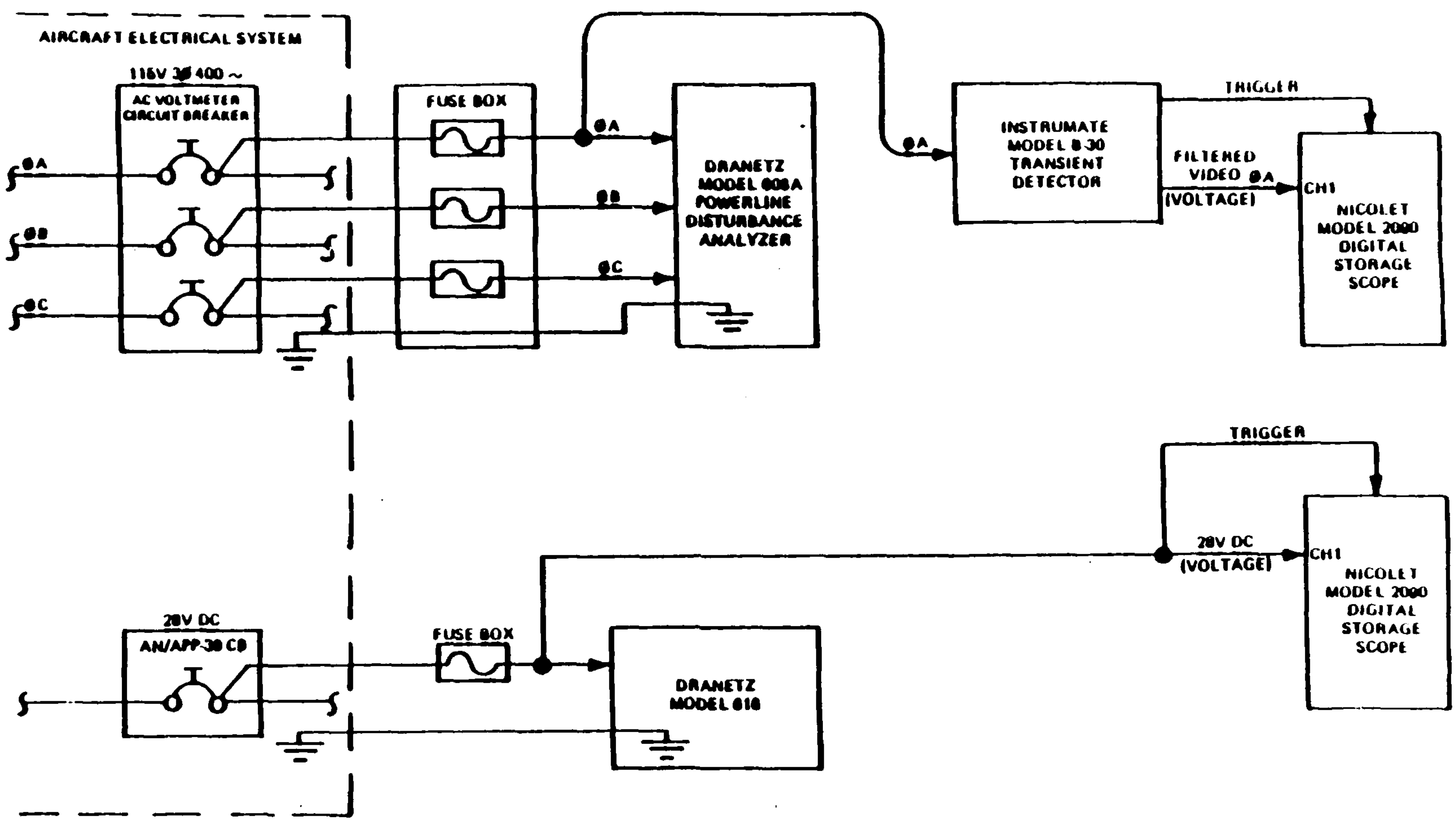



Figure 1: Instrumentation for UH-1N Transient Investigation

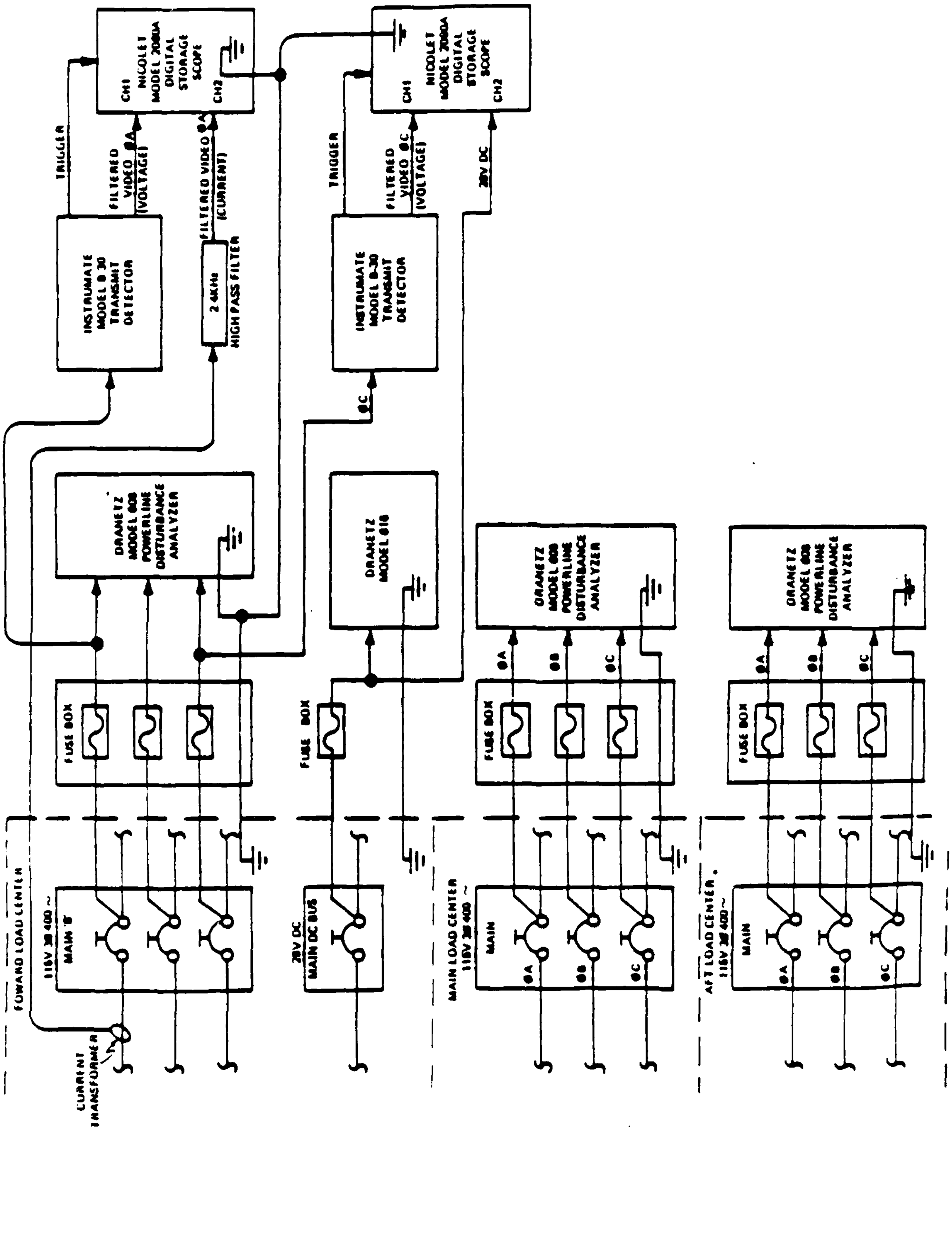



Figure 2: Instrumentation for P-3C Transient Investigation

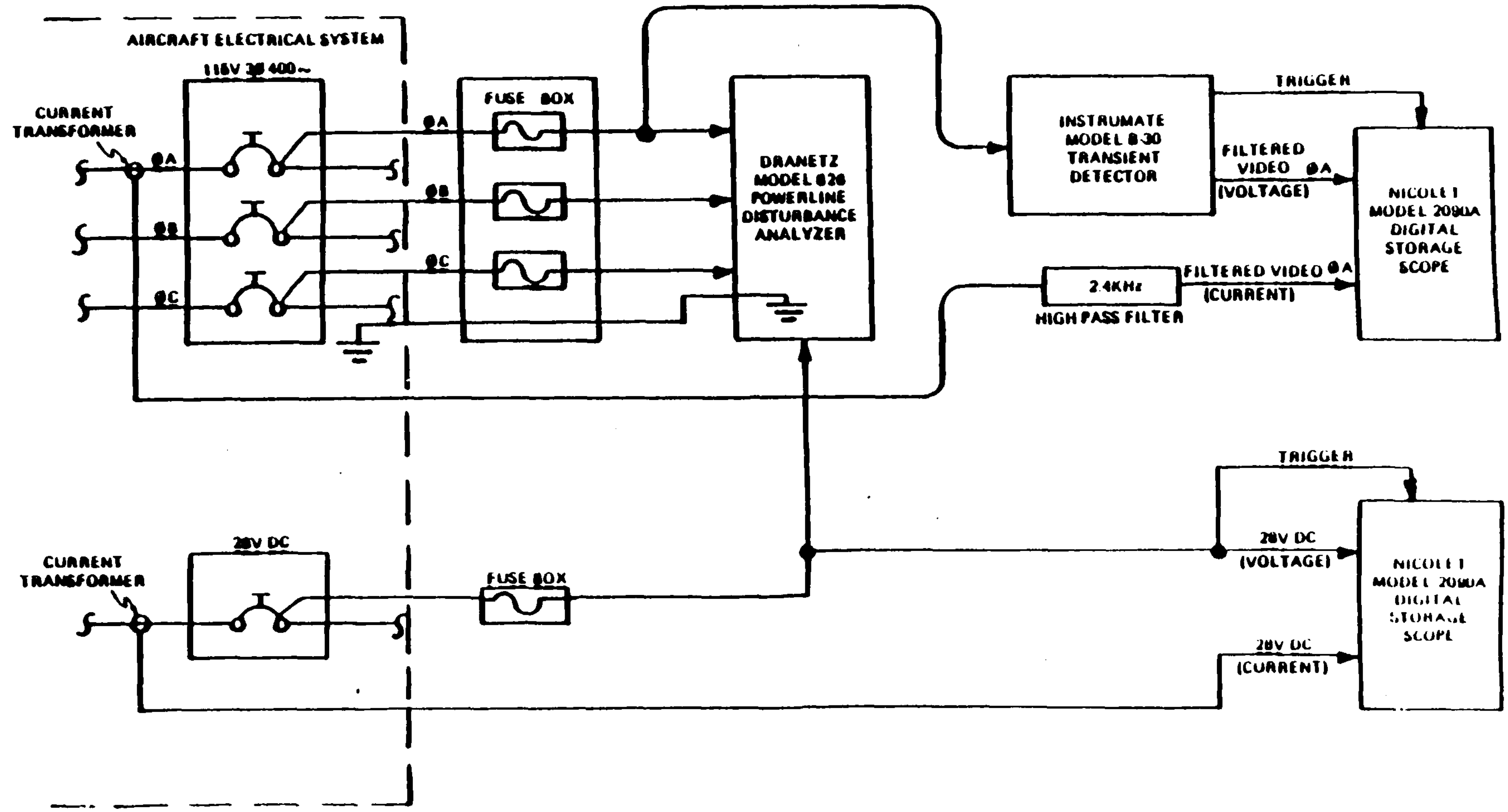



Figure 3: Instrumentation for CH-46E Transient Investigation

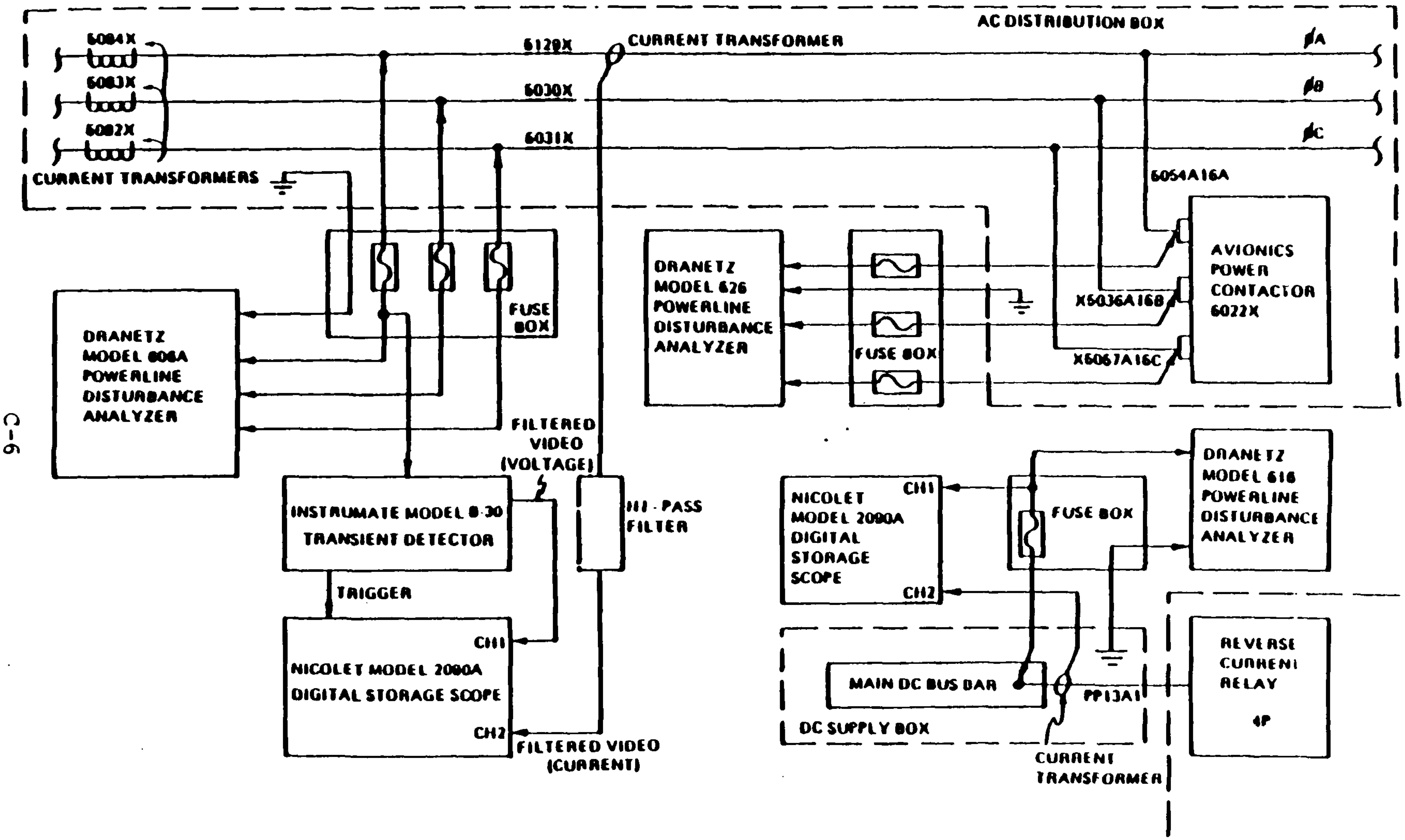



Figure 4: Instrumentation for HU-25A Transient Investigation

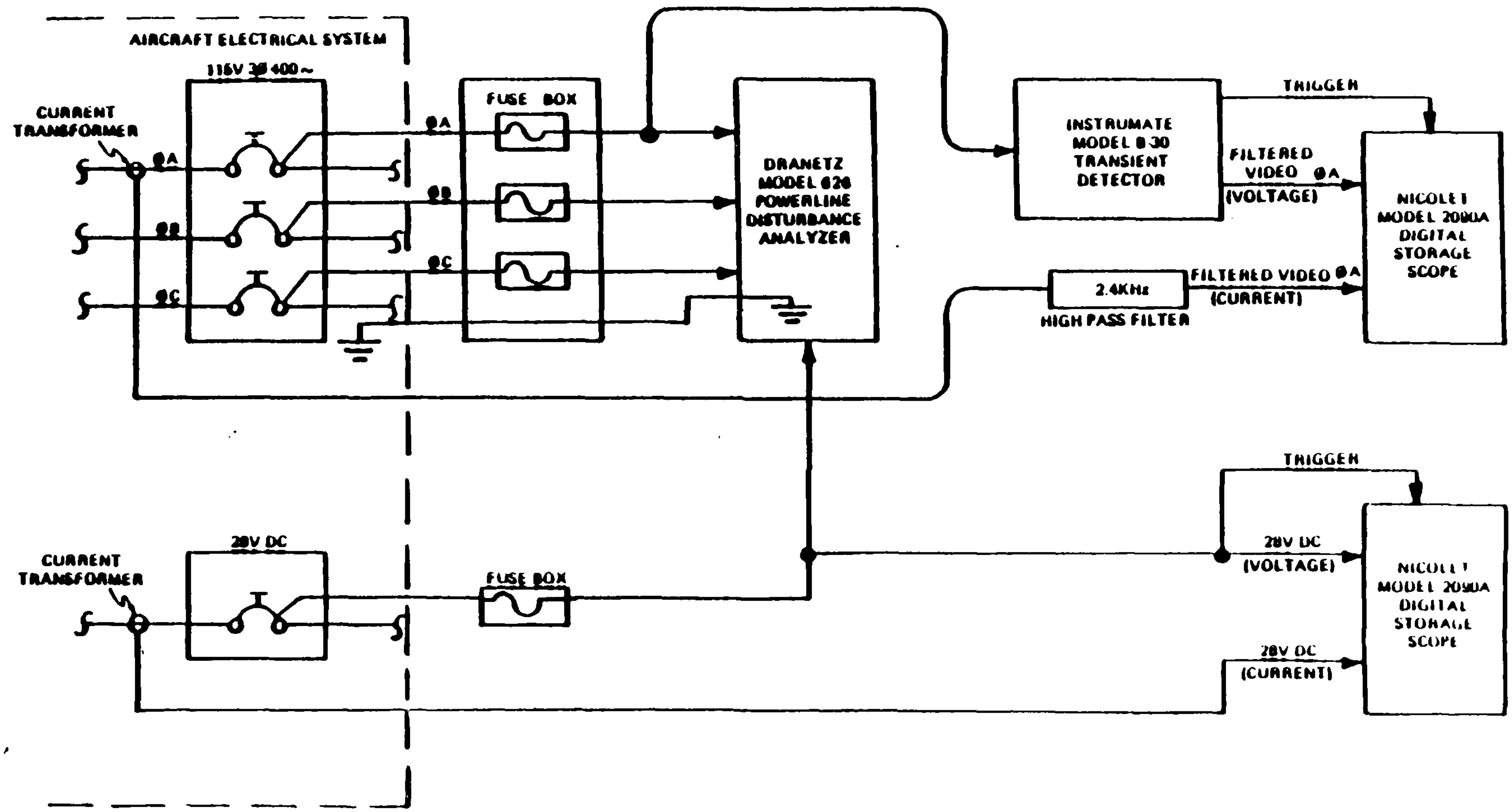



Figure 5: Instrumentation for CH-46E (SR&M) Transient Investigation

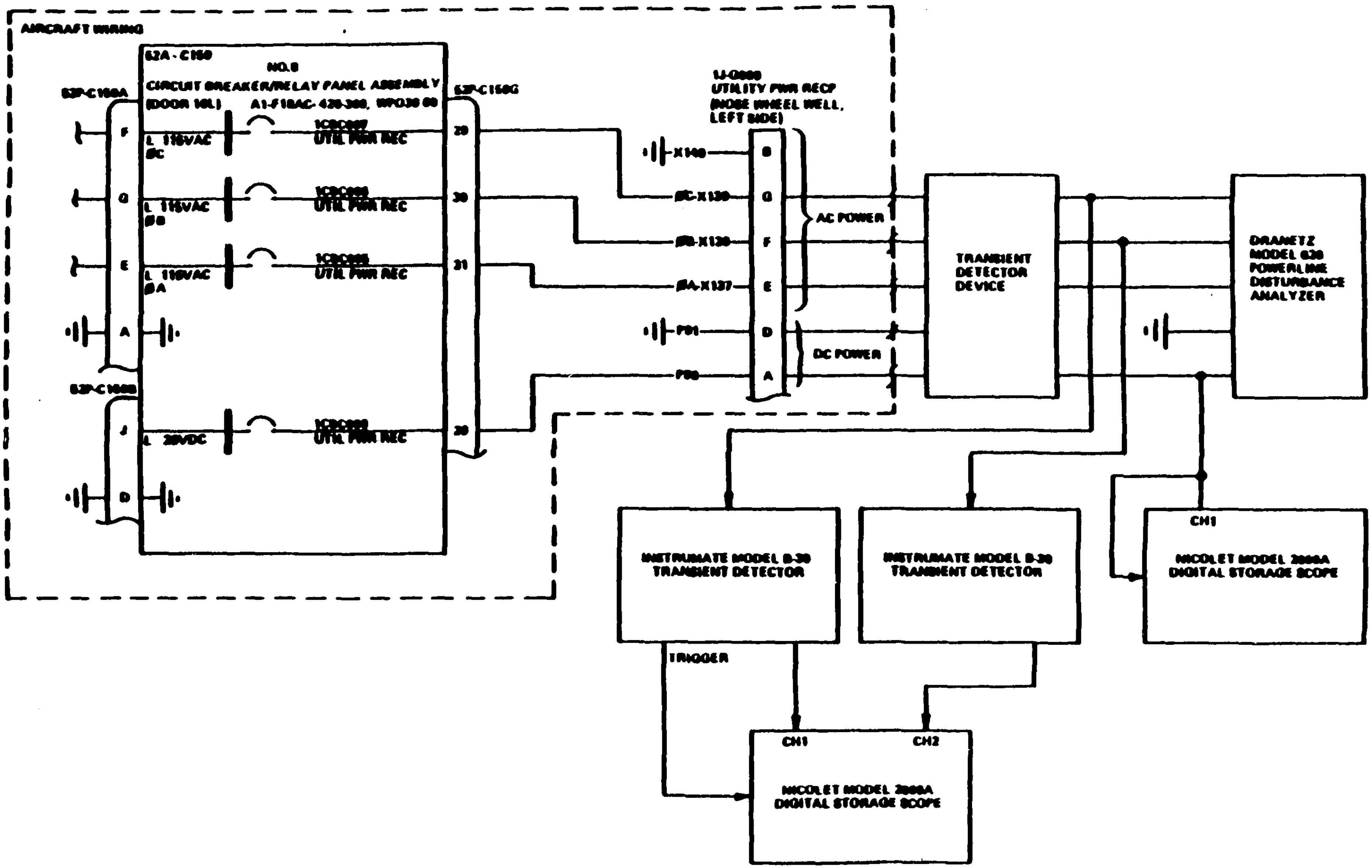



Figure 6: Instrumentation for TF-18A Transient Investigation

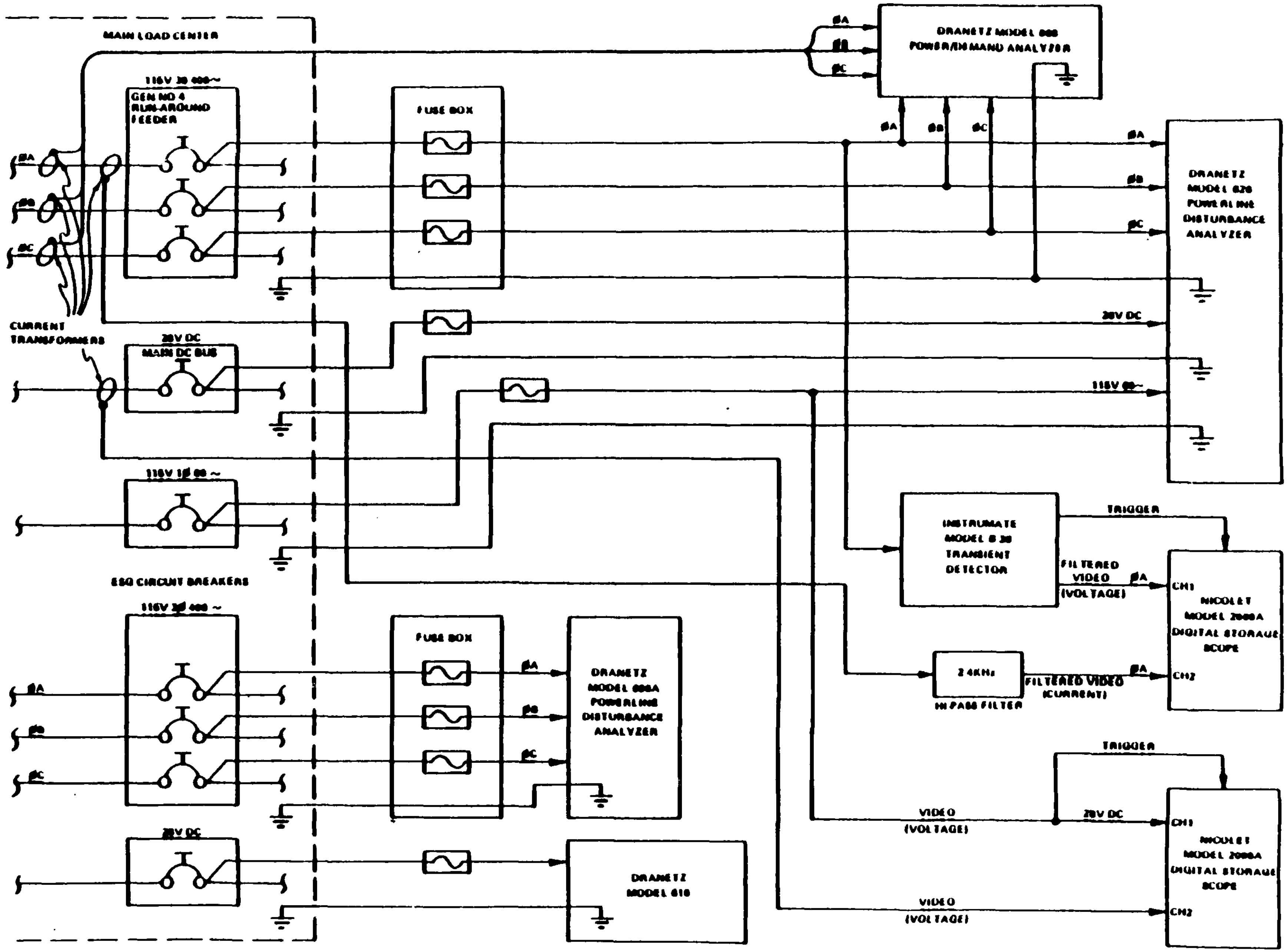



Figure 7: Instrumentation for RP-3D Transient Investigation

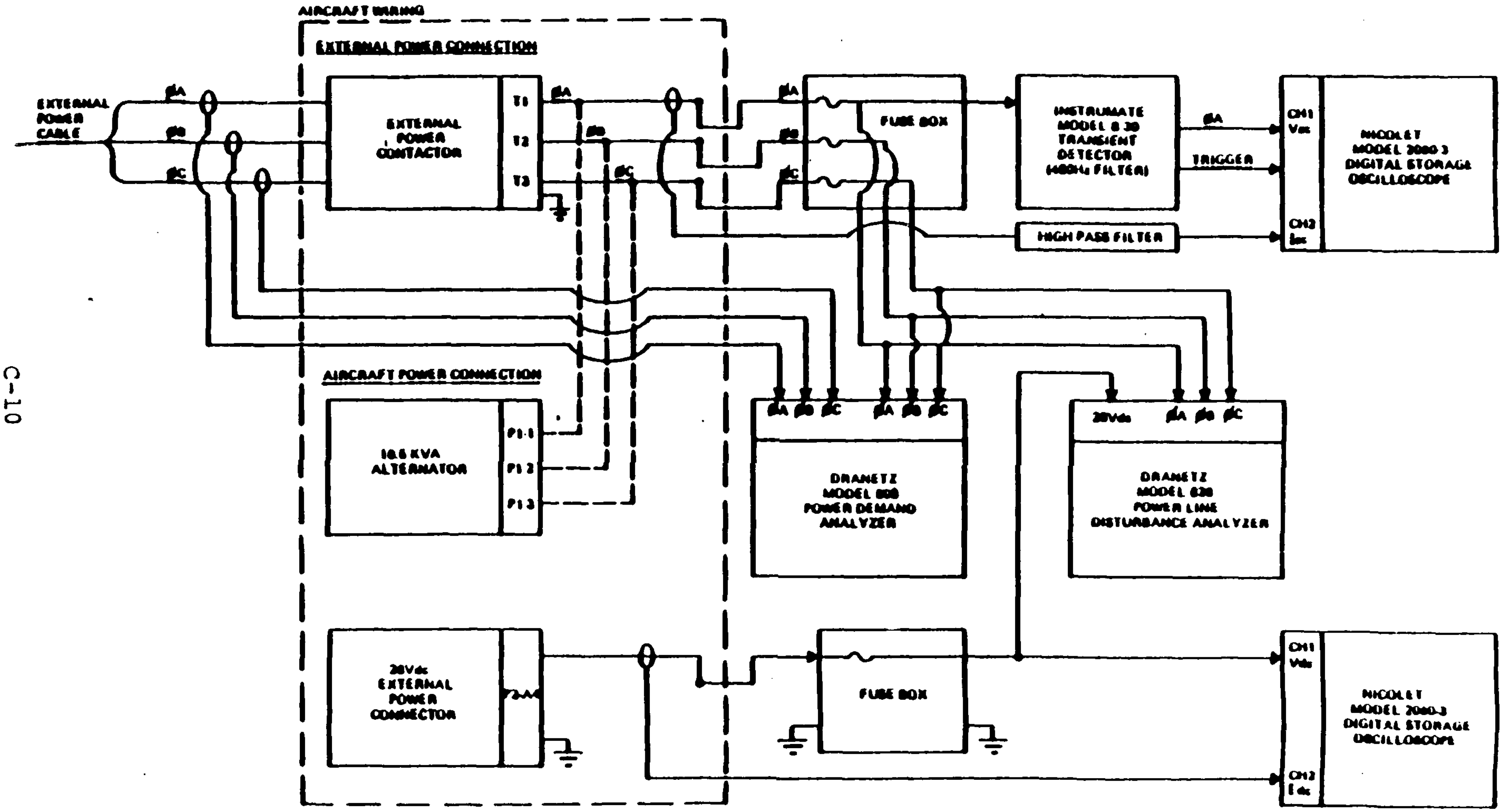



Figure 8: Instrumentation for HH-65A Power Line Investigation

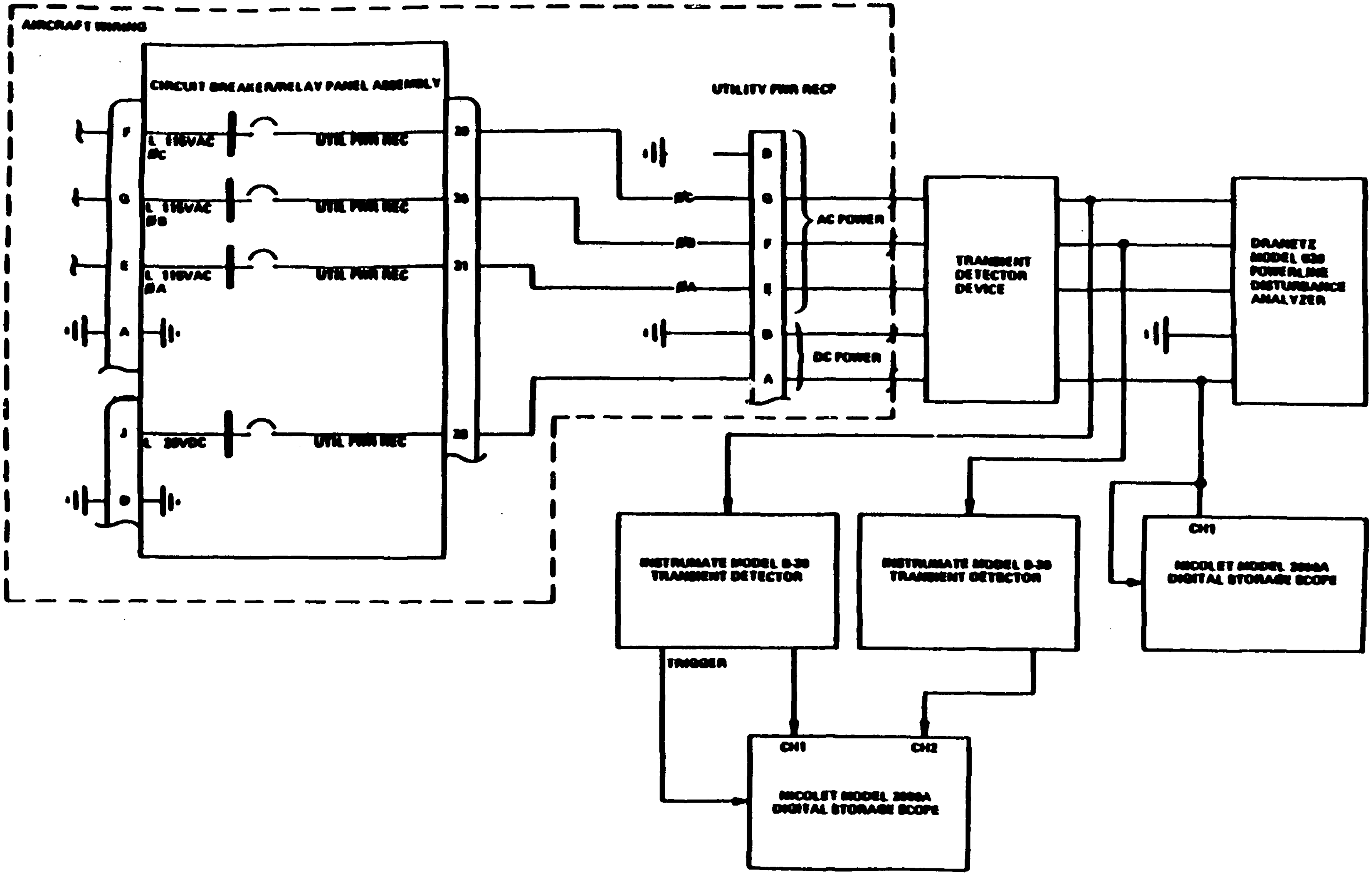



Figure 9: Instrumentation for ATF-2 Transient Investigation

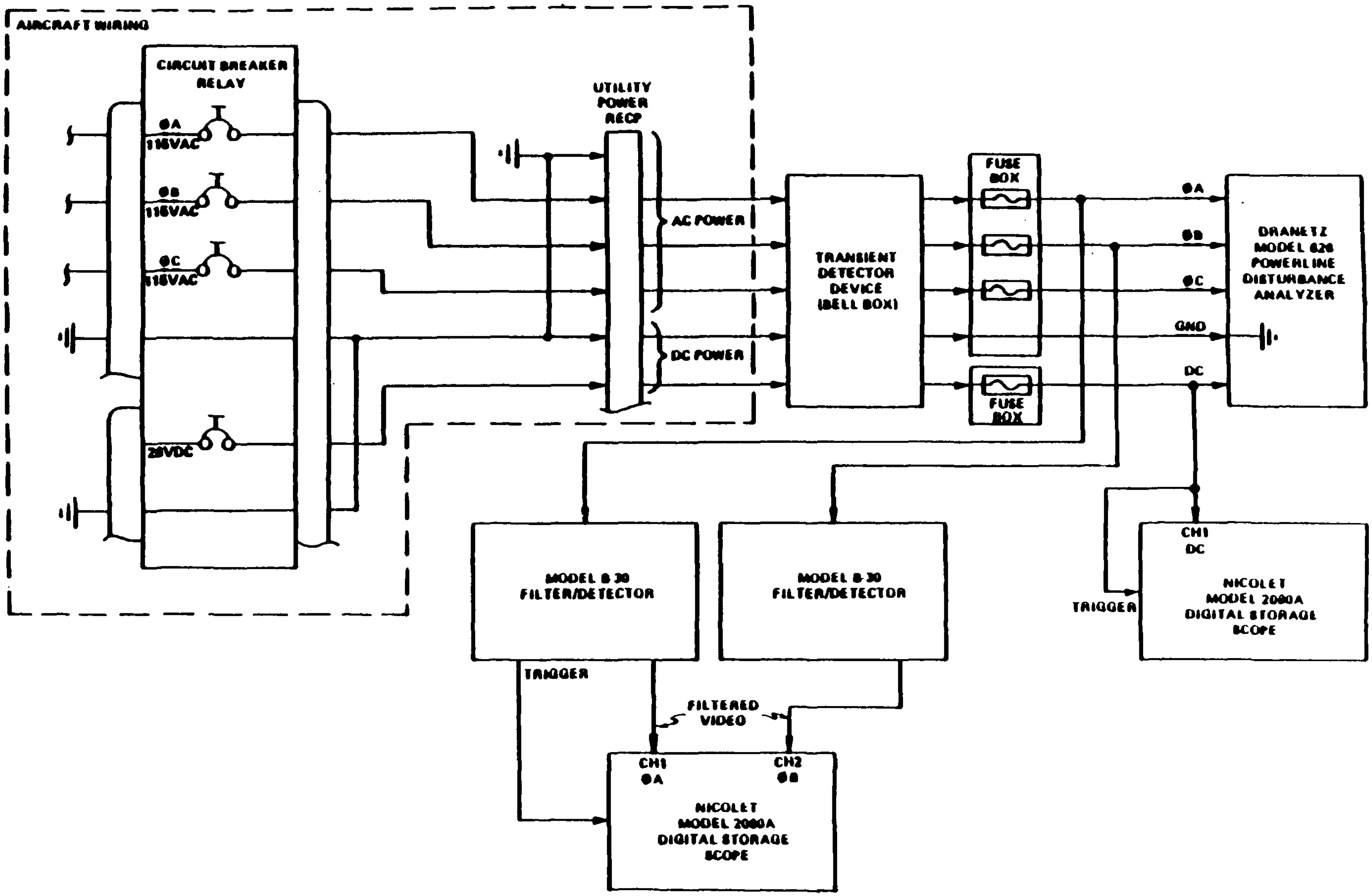



Figure 10: Instrumentation for AV-8B Transient Investigation

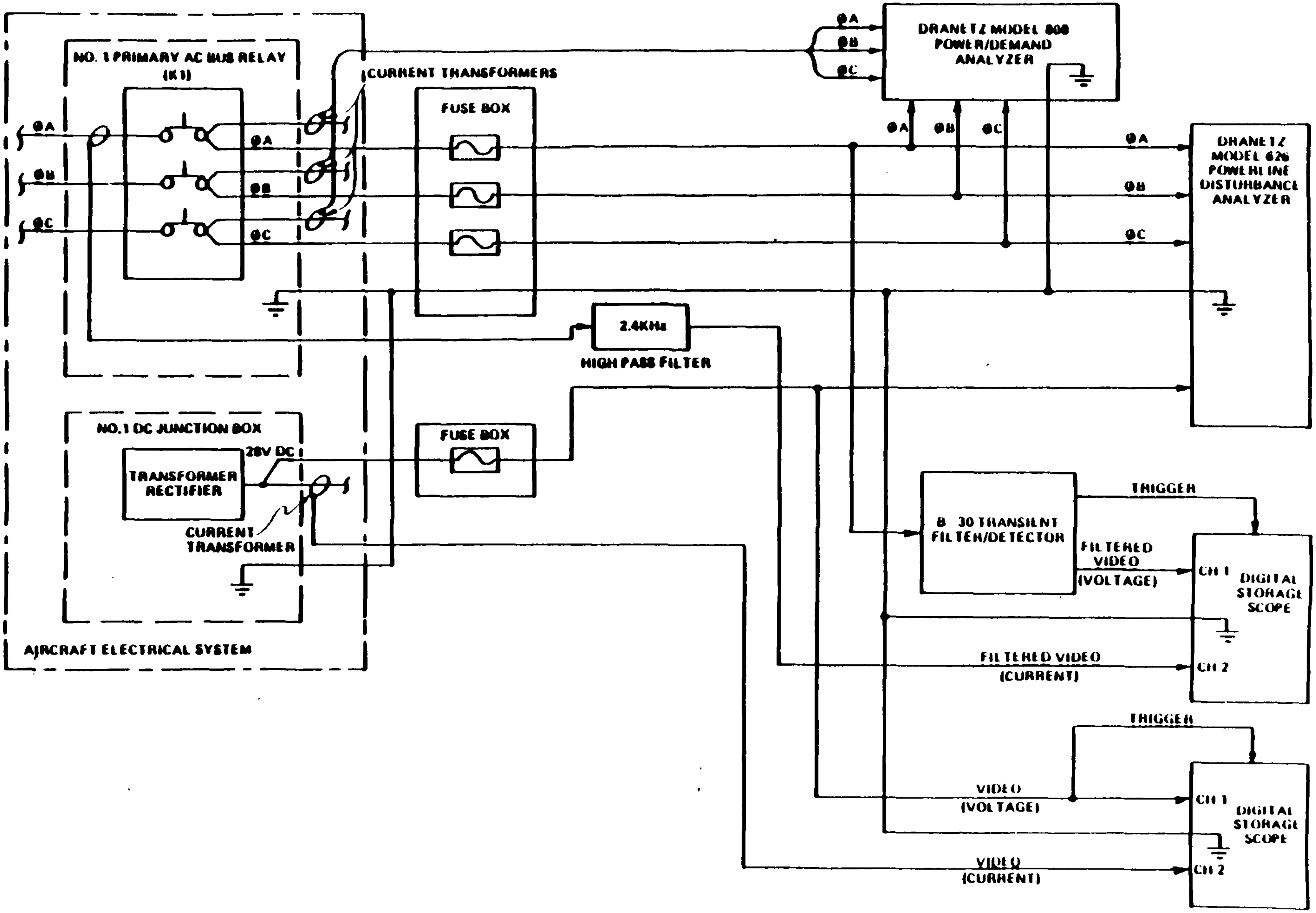



Figure 11: Test Configuration for HH-3F Aircraft

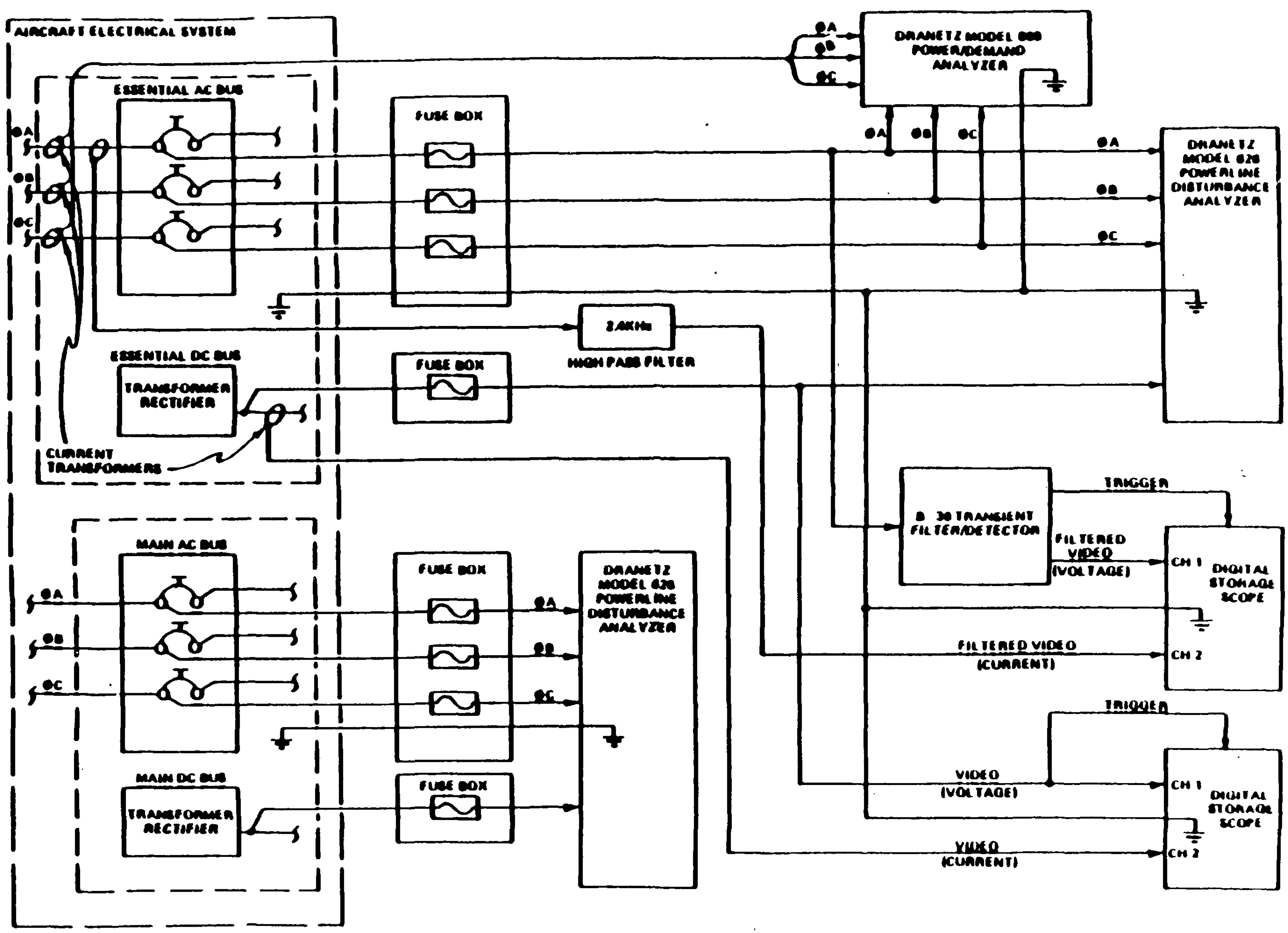



Figure 12: Test Configuration for HC-130H Aircraft

# APPENDIX D
# DATA PRESENTATION

1. INTRODUCTION.

1.1. To record and classify the powerline transient data, a list was developed of the switching operations performed during the tests for each aircraft. The following is an explanation of this list. Also included in this appendix are excerpts from the "event list" (titled "Aircraft Powerline Investigation") from the HC-130H test to further show how the data were organized.

2. DATA PRESENTATION.

2.1. The aircraft power investigation list represents the equipment aboard the aircraft that were cycled manually while data were being recorded.

2.1.1. The event number, on the list, represents the sequence of the manual cycling. The "Disk No." and "Track No." columns provide the disk number and track location of the disturbance recorded by the digital storage oscilloscope. The first "disk/track" column lists the disk number and track location of data recorded on the 28 Vdc bus. The other lists the same information for the 115 Vac bus.

2.1.2. The column labeled "mode" represents the switch positioning of the manual operation being cycled. For example, if event number 1 is shown in the "stand-by" mode and event number 1.1. is shown in the "off" mode, this indicates that the switch being cycled for a particular piece of equipment has been moved from the "standby" position to the "off" position.

2.1.3. The "equipment" column lists the specific equipment or subsystem being cycled.

2.2. The graphs represent the X-Y plots obtained from the digital storage oscilloscope. Disk number and track location information on each plot correspond to the disk number and track number in the "disk track" columns on the aircraft power investigation list.

2.2.1. Some recorded events resulted in more than one transient waveform being represented. More than one recording per event is due to two test conditions. The first is a disturbance occurring whose duration exceeds the sweep length of the digital oscilloscope. The second is when the actuation of a switch results in two distinct equipment or subsystem functions. For example, actuation of "gear-down" switch will result in motors coming on and then automatically shutting off when the extent of mechanical travel is complete.

## NESEA 0263

### AIRCRAFT POWERLINE TRANSIENT INVESTIGATION

AIRCRAFT TYPE: HC-130H

AIRCRAFT ID NO.: CGNR 1713

EVENT LIST NO. 14-2

PAGE ____ OF ____

TEST DATE: 9-20-DEC 85

PERFORMED BY: ____

LOCATION: Elizabeth City, NC

POWER: ✓ APU

GND: ____ AIRCRAFT: X

| EVENT NO. | EVENT PERFORMED: YES/NO | EVENT PERFORMED: IF NO, COMMENT | OSCILLOSCOPE (CH 1: 115Vac ØA; CH 2: [illegible]): Disc No. | OSCILLOSCOPE: Track No. | OSCILLOSCOPE (CH 1: 28V dc; CH 2: [illegible] dc): Disc No. | OSCILLOSCOPE: Track No. | EQUIPMENT/SYSTEM EXERCISED | MODE SEQUENCE (OF EQUIP OR SYS) | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | External Pwr | | Ground Power Cart on |
| 1.1.1 | Yes | | 5A | 1 | 11 | 1 | Ext. Pwr | ON | 3Ø AC 1 |
| 1.1.2 | Yes | | | | 11 | 2 | | OFF | |
| 1.1.3 | Yes | | 5A | 2 | 11 | 3 | | ON | |
| 1.1.4 | Yes | | | | 11 | 4 | | OFF | |
| 1.1.5 | Yes | | 5A | 3 | 11 | 5 | | ON | |
| 1.1.6 | Yes | | | | 11 | 6 | | OFF | |
| | | | | | | | | | |

## NESEA 0263

### AIRCRAFT POWERLINE TRANSIENT INVESTIGATION

AIRCRAFT TYPE: HC-130H

AIRCRAFT ID NO.: CGNR 1713

EVENT LIST NO. 14-2

PAGE ____ OF ____

TEST DATE: 9-20-DEC 85

PERFORMED BY:

LOCATION: Elizabeth City, NC

POWER: ✓ APU

GND: ____ AIRCRAFT: X

| EVENT NO. | EVENT PERFORMED | | OSCILLOSCOPE CH 1: 115 Vac ØA, CH 2: ... ØB | | OSCILLOSCOPE CH 1: 28V dc, CH 2: I dc | | EQUIPMENT/SYSTEM EXERCISED | MODE SEQUENCE (OF EQUIP OR SYS) | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|
| | YES NO | IF NO, COMMENT | Disc No. | Track No. | Disc No. | Track No. | | | |
| 1.1.7 | Yes | | 5A | 4 | 11 | 8 | | ON | |
| | | | | | | | APU Pwr | | |
| 1.2.1 | Yes | | | | | | Batt Sw | ON | 2 |
| 1.2.2 | Yes | | | | | | Bus Tie Sw | ON | 3 |
| 1.2.3 | Yes | | | | | | APU Start Sw | RUN | 3 |
| 1.2.3.1 | Yes | | | | 12 | 1 | APU Start seq. | START | Spring loaded 3 |
| 1.2.4 | Yes | | | | | | | RUN | 5 sec only 3 |
| | | | | | | | | | |

# NESEA 0263

## AIRCRAFT POWERLINE TRANSIENT INVESTIGATION

AIRCRAFT TYPE: HC-130H

AIRCRAFT ID NO.: CGNR 1713

EVENT LIST NO. 14-2

PAGE ____ OF ____

TEST DATE: 9-20-DEC 85

PERFORMED BY: ______

LOCATION: Elizabeth City, NC

POWER: / APU

GND: ____ AIRCRAFT: X

| EVENT NO. | EVENT PERFORMED: YES / NO | EVENT PERFORMED: IF NO, COMMENT | OSCILLOSCOPE (CH 1: 115 Vac ØA; CH 2: [illegible]): Disc No. | OSCILLOSCOPE: Track No. | OSCILLOSCOPE (CH 1: 28V dc; CH 2: [illegible] dc): Disc No. | OSCILLOSCOPE: Track No. | EQUIPMENT/SYSTEM EXERCISED | MODE SEQUENCE (OF EQUIP OR SYS) | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|
| 1.2.5 | Yes | | | | | | | OFF | 3 |
| 1.2.6 | Yes | | | | | | Bus Tie Sw | OFF | 3 |
| 1.2.7 | Yes | | | | | | Batt Sw | OFF | 2 |
| 1.2.8 | Yes | | | | | | Batt Sw | ON | |
| 1.2.9 | Yes | | | | | | Bus Tie Sw | ON | |
| 1.2.10 | Yes | | | | | | APU Start Sw | RUN | |
| 1.2.10.1 | Yes | | | | 12 | 2 | APU | START | Spring loaded |
| | | | | | | | | | |

## NESEA 0263

### AIRCRAFT POWERLINE TRANSIENT INVESTIGATION

AIRCRAFT TYPE: HC-130H

AIRCRAFT ID NO.: CGNR 1713

EVENT LIST NO. 14-2

PAGE ___ OF ___

TEST DATE: 9-20-DEC 85

PERFORMED BY:

LOCATION: Elizabeth City, NC

POWER: APU

GND: ___ AIRCRAFT: X

| EVENT NO. | EVENT PERFORMED YES/NO | IF NO, COMMENT | OSCILLOSCOPE (CH 1: 115 Vac ØA; CH 2: 3ac ØA) Disc No. | Track No. | OSCILLOSCOPE (CH 1: 28V dc; CH 2: 3 dc) Disc No. | Track No. | EQUIPMENT/SYSTEM EXERCISED | MODE SEQUENCE (OF EQUIP OR SYS) | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|
| 1.2.11 | Yes | | | | | | | RUN | 5 sec only |
| 1.2.12 | Yes | | | | | | | OFF | |
| 1.2.13 | Yes | | | | | | Bus Tie Sw | OFF | |
| 1.2.13.1 | Yes | | | | | | Batt Sw | OFF | |
| 1.2.14 | Yes | | | | | | Batt Sw | ON | |
| 1.2.15 | Yes | | | | | | Bus Tie Sw | ON | |
| 1.2.16 | Yes | | | | 12 | 3 | APU Start Sw | RUN | |

# NESEA 0263

## AIRCRAFT POWERLINE TRANSIENT INVESTIGATION

AIRCRAFT TYPE: HC-130H

AIRCRAFT ID NO.: CGNR 1713

EVENT LIST NO. 14-2

PAGE ____ OF ____

TEST DATE: 9-20-DEC 85

PERFORMED BY:

LOCATION: Elizabeth City, NC

POWER: ✓ APU

GND: ____ AIRCRAFT: X

| EVENT NO. | EVENT PERFORMED: YES / NO | EVENT PERFORMED: IF NO, COMMENT | OSCILLOSCOPE (CH 1: 115 Vac ØA; CH 2: ... ac ØB): Disc No. | OSCILLOSCOPE (CH 1: 115 Vac ØA; CH 2: ... ac ØB): Track No. | OSCILLOSCOPE (CH 1: 28V dc; CH 2: ... dc): Disc No. | OSCILLOSCOPE (CH 1: 28V dc; CH 2: ... dc): Track No. | EQUIPMENT/SYSTEM EXERCISED | MODE SEQUENCE (OF EQUIP OR SYS) | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|
| 1.2.16.1 | Yes | | | | 12 | 4 | APU | START | Spring loaded |
| 1.2.17 | Yes | | | | | | | RUN | (Leave running) |
| 1.2.18 | Yes | | | | | | APU Gen | ON | Pwr to essential ac system 2 |
| 1.2.18.1 | Yes | | | | 12 | 5 | AC Bus Tie Sw | ON | Pwr to main ac sys. |
| | | | | | | | Aircraft Eng Pwr | | |
| 1.3.1 | Yes | | | | 12 | 6 | Engine Inst Inv | ON | 3 |
| 1.3.2 | Yes | | | | 12 | 7&8 | Aux hyd. pump | ON | 2 |
| | | | | | | | | | |

APPENDIX E

TRANSIENT DATA PLOTS

1. INTRODUCTION.

1.1. Several plots of transient data are included to demonstrate how the data were presented for statistical analysis and to give examples of the predominant waveforms encountered throughout the investigation. All of the data plots were produced, using either an HP9830A calculator or an HP9836 computer, from the floppy disk recordings of the powerline transients.

PROJECT: F-3C 120V AC CH.1

DISK NUMBER 12 A. TRACK NUMBER 6

EVENT NUMBER 48 A.

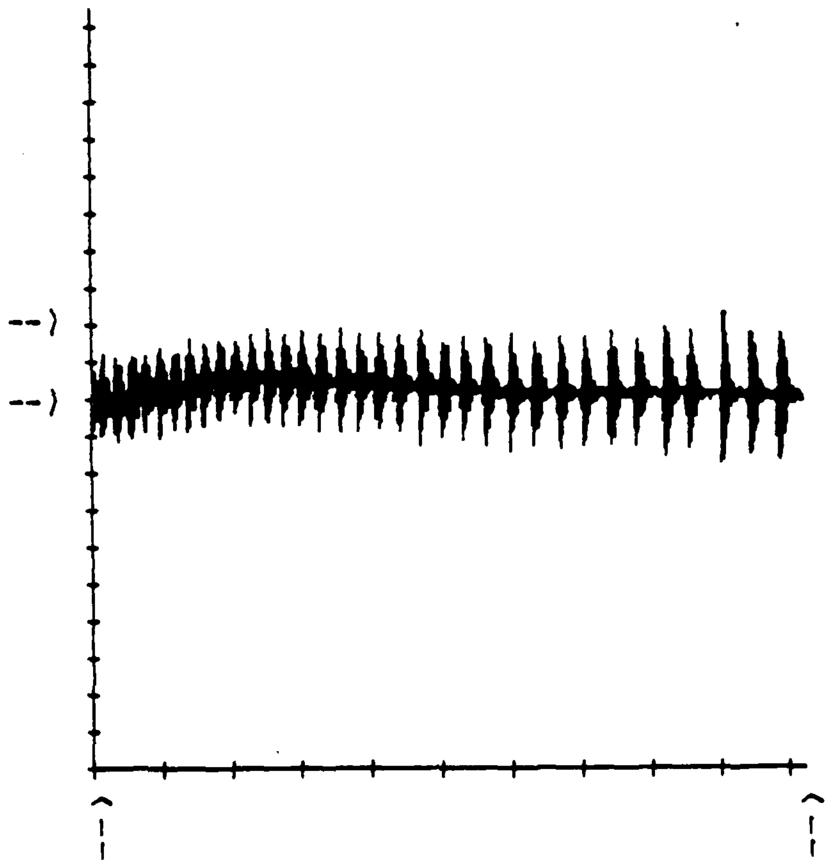
PEAK VOLTAGE= 8.64 VOLTS

PULSE WIDTH = 204.3 MICROSECONDS

MEASURED BETWEEN ARROWS

VOLTS/DIV.= 4 VOLTS

TIME/DIV.= 20 MICROSECONDS



PROJECT: P-3C +28V DC

DISK NUMBER 2 TRACK NUMBER 8

EVENT NUMBER 11 A.

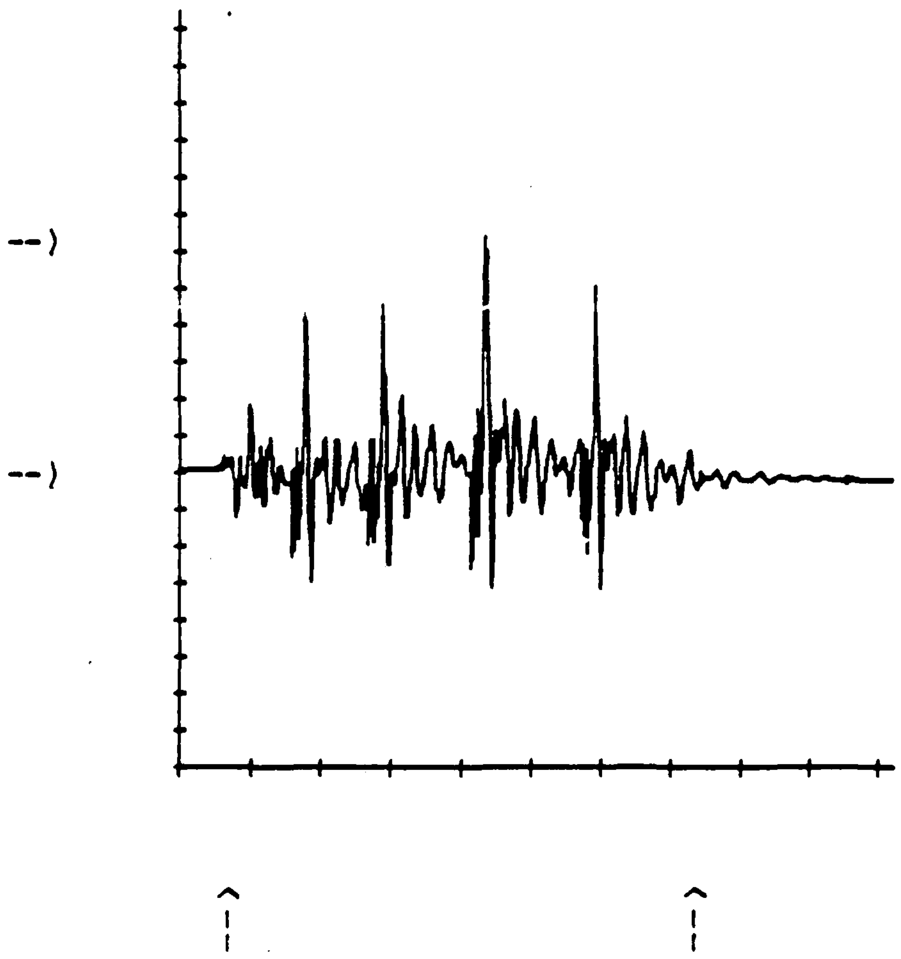
PEAK VOLTAGE= 1.264 VOLTS

PULSE WIDTH = 66.85 MICROSECONDS

MEASURED BETWEEN ARROWS

VOLTS/DIV.= 0.2 VOLTS

TIME/DIV.= 10 MICROSECONDS

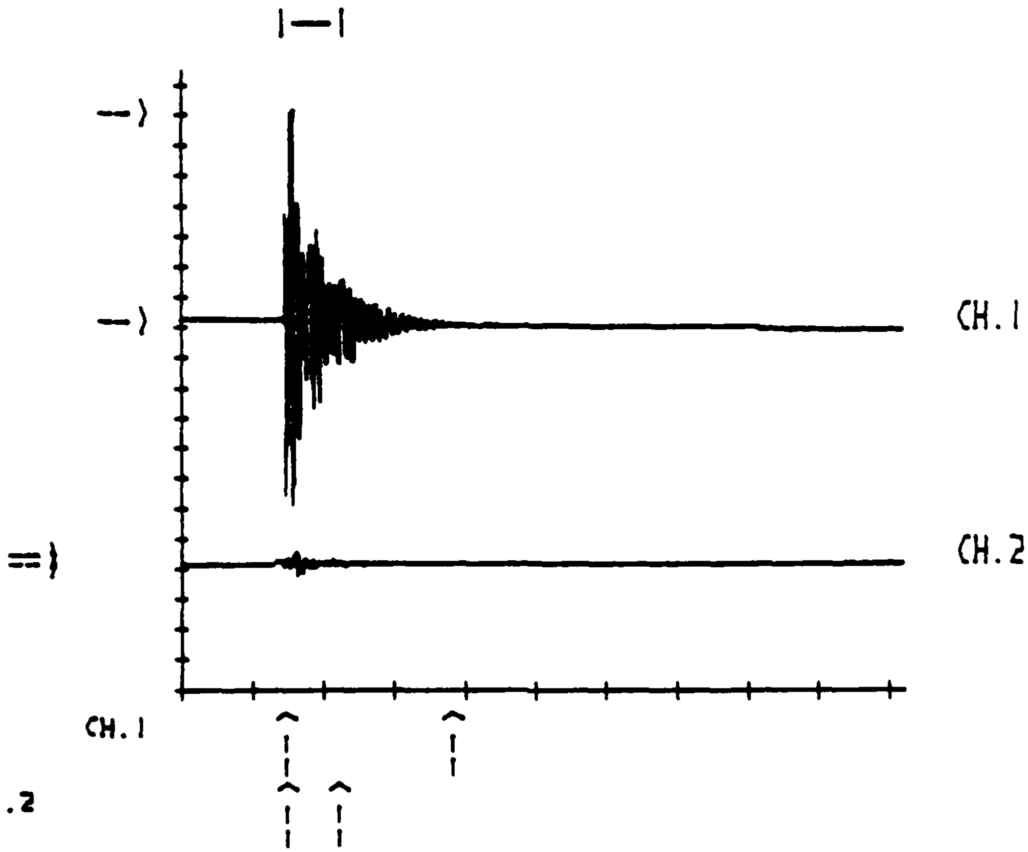


PROJECT: RP-3D 28V DC
DISK NUMBER 40. TRACK NUMBER 1
EVENT NUMBER 3.2.19.

| | |
|---|---|
| MAX PEAK POWER= 1.536 WATTS | DURING ENTIRE SWEEP INTERVAL |
| TOTAL ENERGY= -6.11328E-07 JOULES | MEASURED BETWEEN MARKERS \|— —\| |

| | |
|---|---|
| PEAK VOLTAGE = 6.88 VOLTS CH.1<br>PEAK CURRENT = 0.32 AMPS CH.2<br>PULSE WIDTH = 9.4 MICROSECONDS CH.1<br>PULSE WIDTH = 2.94 MICROSECONDS CH.2 | MEASURED BETWEEN ARROWS |

PER DIV.= 1 VOLTS CH.1/ 1 AMPS CH.2
TIME/DIV.= 4 MICROSECONDS



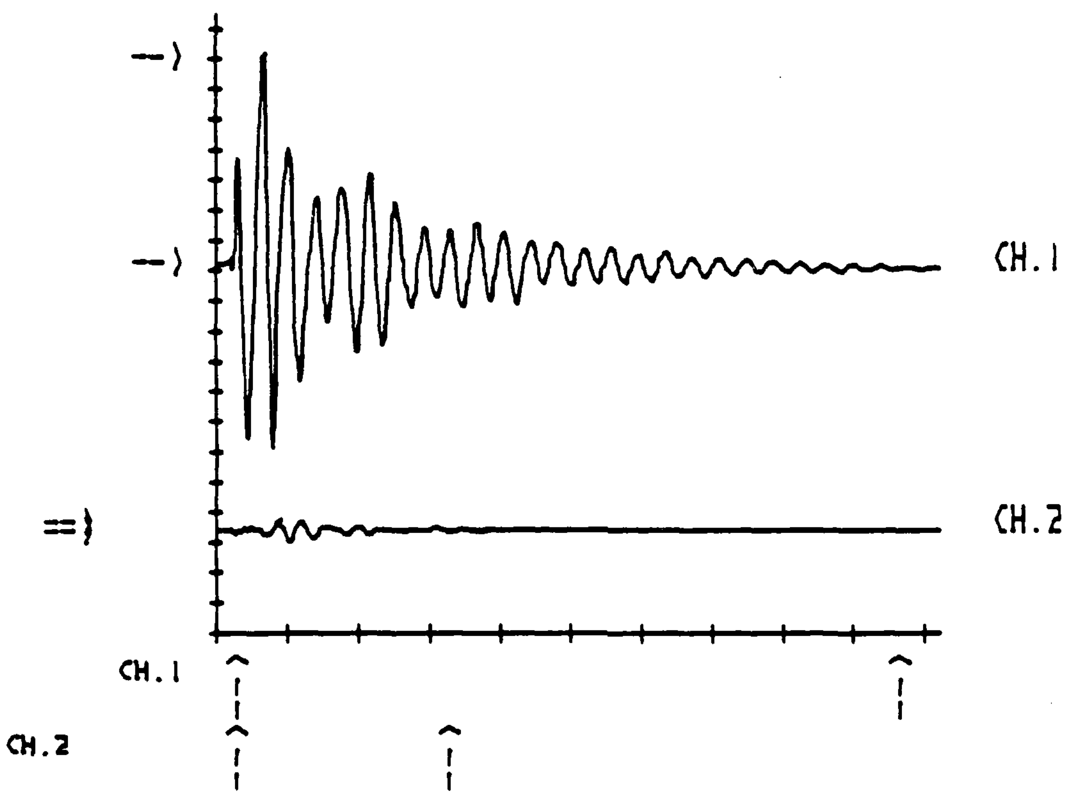



PLOT 347

PROJECT: RP-3D 28V DC ( EXPANDED )
DISK NUMBER 40. TRACK NUMBER 1
EVENT NUMBER 3.2.19.

| | |
|---|---|
| PEAK VOLTAGE = 6.8 VOLTS CH.1<br>PEAK CURRENT = 0.32 AMPS CH.2<br>PULSE WIDTH = 9.38 MICROSECONDS CH.1<br>PULSE WIDTH = 3 MICROSECONDS CH.2 | MEASURED<br>BETWEEN<br>ARROWS |

PER DIV.= 1 VOLTS CH.1/ 1 AMPS CH.2
TIME/DIV.= 1 MICROSECONDS



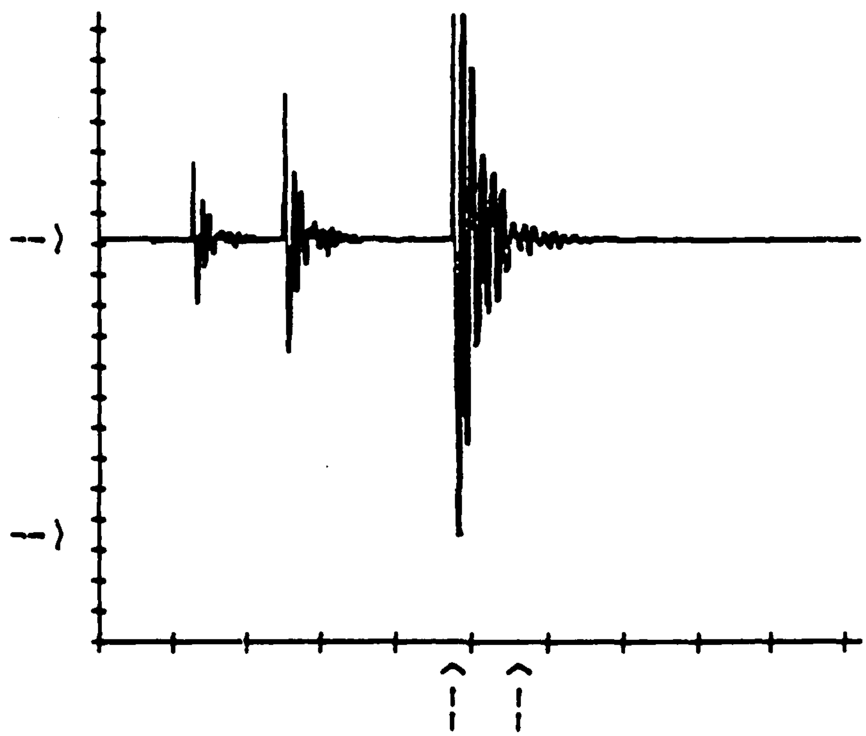



PLOT 343

PROJECT: HH-3F CGNR 1483 INFLIGHT (28VDC)
DISK NUMBER 1 TRACK NUMBER 6
EVENT NUMBER RANDOM

| PEAK VOLTAGE= -9.68 VOLTS<br><br>PULSE WIDTH = 1.7 MICROSECONDS | MEASURED BETWEEN ARROWS |
|---|---|

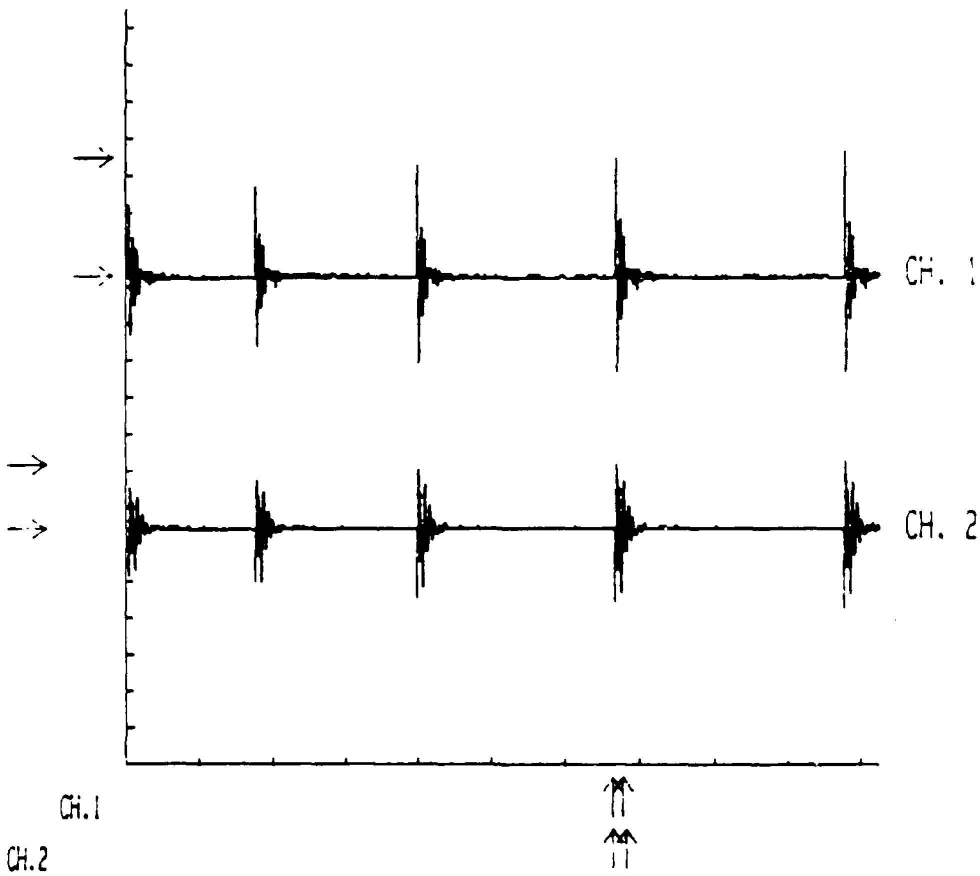
VOLTS/DIV.= 1 VOLTS
TIME/DIV.= 2 MICROSECONDS



PROJECT: HH-3F CGNR 1483 INFLIGHT (28VDC)
DISK NUMBER: 12 TRACK NUMBER: 4
EVENT NUMBER: RANDOM

| | |
|---|---|
| PEAK VOLTAGE = 12.8 VOLTS, CH. 1<br>PULSE WIDTH = .56 MICROSECONDS, CH. 1<br>PEAK VOLTAGE = 7.04 VOLTS, CH. 2<br>PULSE WIDTH = .72 MICROSECONDS, CH. 2 | MEASURED BETWEEN ARROWS |

PER/DIV. = 4 VOLTS CH. 1, 4 VOLTS CH. 2
TIME/DIV.= 4 MICROSECONDS



PROJECT: HH-3F CGNR 1483 INFLIGHT (28VDC) ( EXPANDED )

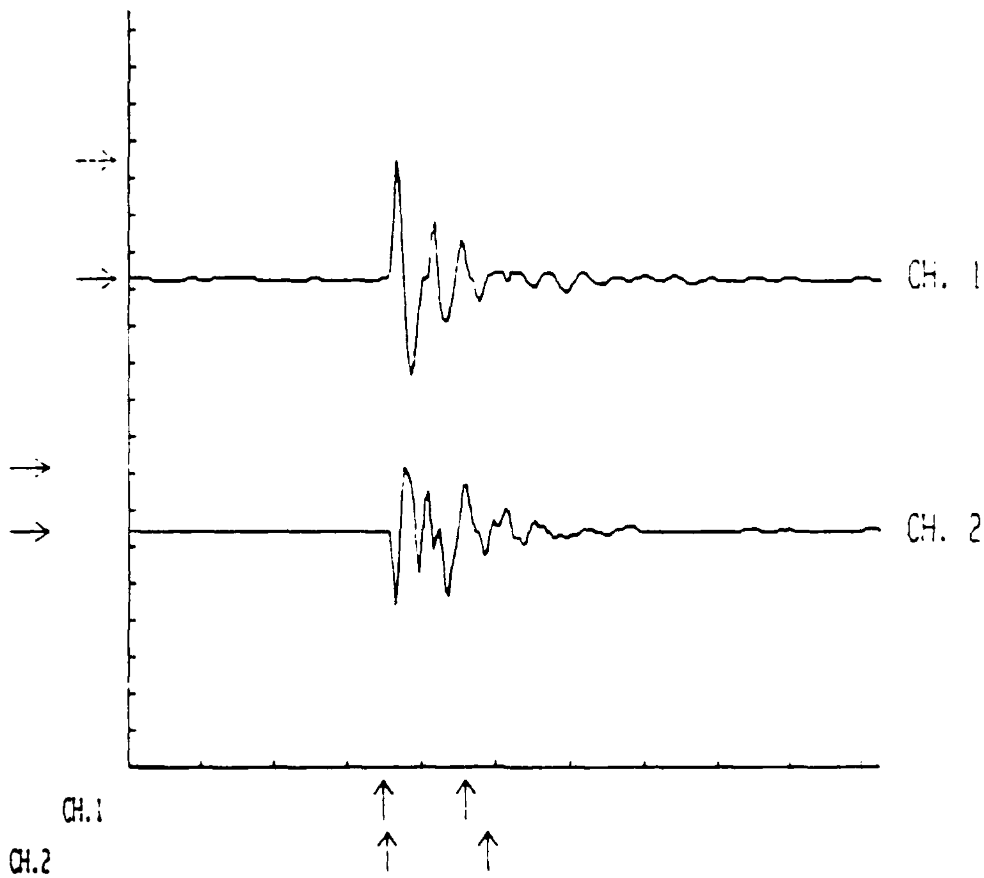
DISK NUMBER: 12 TRACK NUMBER: 4

EVENT NUMBER: RANDOM

| | |
|---|---|
| PEAK VOLTAGE = 12.8 VOLTS, CH. 1<br>PULSE WIDTH = .56 MICROSECONDS, CH. 1<br>PEAK VOLTAGE = 7.04 VOLTS, CH. 2<br>PULSE WIDTH = .68 MICROSECONDS, CH. 2 | MEASURED BETWEEN ARROWS |

PER/DIV. = 4 VOLTS CH. 1, 4 VOLTS CH. 2

TIME/DIV.= .5 MICROSECONDS

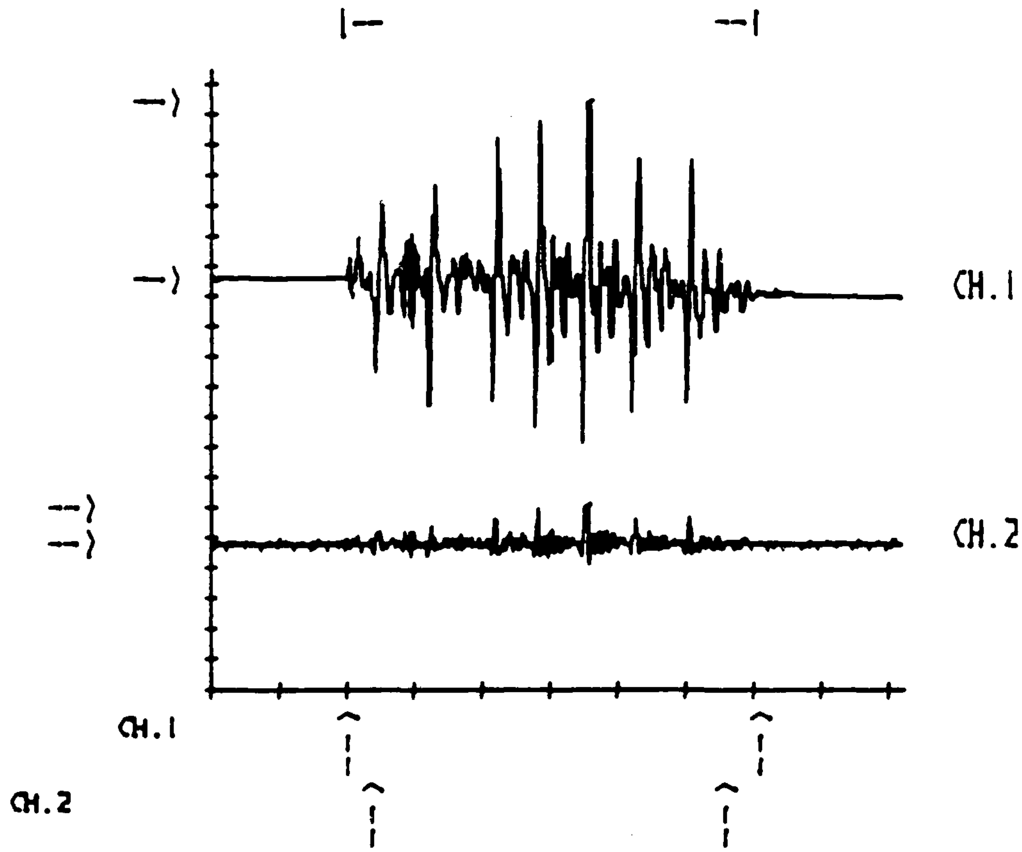


PROJECT: CH-46E SRAM 28V DC
DISK NUMBER 3. TRACK NUMBER 5
EVENT NUMBER 2 D.

| | |
|---|---|
| MAX PEAK POWER= 0.3072 WATTS | DURING ENTIRE SWEEP INTERVAL |
| TOTAL ENERGY= -1.10592E-07 JOULES | MEASURED BETWEEN MARKERS<br>\|— —\| |

| | |
|---|---|
| PEAK VOLTAGE = 5.84 VOLTS CH.1<br>PEAK CURRENT = 0.12 AMPS CH.2<br>PULSE WIDTH = 60.9 MICROSECONDS CH.1<br>PULSE WIDTH = 52.1 MICROSECONDS CH.2 | MEASURED<br>BETWEEN<br>ARROWS |

PER DIV.= 1 VOLTS CH.1/ 0.1 AMPS CH.2
TIME/DIV.= 10 MICROSECONDS



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19. ABSTRACT (Continue on reverse if necessary and identify by block number)


An investigation into the extent and nature of switching transients on aircraft powerlines showed that both "on ground" and "in-flight" conditions are similar. The data also indicated that, of the transients resulting from switching operations and lasting less than 50 microseconds, more than 95% are similar to damped sinusoidal waveforms or unipolar waveforms; all are below 200V peak on the 115 Vac bus (400 Hz) and 24V peak on the 28 Vdc bus; 94% are below 25V on the 115 Vac (400 Hz) bus; and 82% are below 0.5V on the 28 Vdc bus.

Based on the findings, for test method CE07 in MIL-STD-461, Part 2 (Aircraft), the present levels are adequate and should be retained. For test method CS06:


(continued on reverse)

| | |
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| Mr. L. R. Bachman | (301) 862-8263 | |

a. The requirements should be modified to include two damped sinusoidal waveforms having a Q of 6, frequencies of 1.0 and 10.0 MHz and a peak amplitude at 200V for 115 Vac, 400 Hz powerlines. This requirement should also be added for 28 Vdc lines; however, the amplitude should be reduced to 24V peak.

b. The unipolar pulse with the present time durations should be retained except that the amplitude for the dc powerline should be reduced to 24V peak. (SDW)